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THE SMELL OF ALTRUISM

Incidental pleasant odors and chemosignal as prosocial decisions moderators

by

Valentina Perrotta

Advisor:

Prof. Nicolao Bonini

School Coordinator:

Prof. Paola Venuti

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To my mother

"Odors have a power of persuasion stronger than that of words, appearances, emotions, or will. The persuasive power of an odor cannot be fended off, it enters into us like breath into our lungs, it fills us up, imbues us totally. There is no remedy for it."

P. Süskind

List of Papers

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and more generous. *Emotion.*

Abstract

The study of the interactions between olfaction and the decision making processes has mainly focused on the investigation of what is considered the most useful odor to disperse in the air to drive the consumers' choices to prefer a product rather than another one. Despite the fact that some studies showed the existence of associations between odors and prosocial behavior, much less data are available on the links between olfaction and donation in favor of public goods. Thus, the main purpose of the series of experiments described in this thesis is precisely that to shed some light on the investigation of the nature of pleasant odor-decision and on the chemosignal-decision associations.

In order to achieve this, the presence of an odor and the congruence between odor and decision task has been manipulated, and the decision to donate has been tested in different domains.

Therefore, in the first series of experiments, we manipulated the presence of an ambient pleasant odor, expecting that the congruent stimuli sharing the

more stable association odor-concept, would have resulted in an overall increase in the WTC (willingness to contribute) and WTP (willingness to pay) in the decision to donate in favor of a public good. The results confirmed the existence of an association between the olfactory stimulus congruence and the amount donated in favor of a public good. Interestingly, this effect is confirmed in both hypothetical and real decision settings. Moreover, the stimulus modality was manipulated presenting congruent olfactory or visual stimuli. Our findings confirmed the preferential link between olfaction and cognitive processes and showed higher donations in the olfactory setting (compared to the visual one).

The existence of associations between odors and words are examined to know if the odors could semantically drive cognitive processes different from decision making. The results confirmed the existence of an association between the olfactory stimulus pleasantness and the performance in a lexical decision task (LDT). Thus, this effect is mediated by the presence of a pleasant odor and not by the semantic congruence between odor and the presented words. Moreover, the visual modality tend to worsen the LDT performance even if the visual stimulus was semantically congruent with the word presented.

Finally, even though the semantic link appears to be crucial for cognitive processes such as decision, it seems not so important for memory and linguistic processes involved in the LDT.

The second series of studies involved the presence of chemosignal, expecting that the congruity between stimulus and decision (the chemosignal used is AND, known as the best candidate to be considered a human chemosignal) would have resulted in an overall increase in amount of money donate to unknown persons during Dictator and Trust Game. The results confirmed the

existence of an association between the chemosignal stimulus presence (and its olfactory experience) and the amount donated, and a mediation effect due to the positive mood (in presence of AND) especially in females and with high AND concentration.

Contents

Part I

Introduction

The informations that we can extrapolate from the olfactory stimuli are beyond our control. In many unexpected ways, the odors influences our life, everyday. For instances, guiding us to some aliments and save us from danger situation, such as spoiled foods, gas leaks or fires. The importance of odors is not only linked to bad adventures, but also to some of the more pleasure experiences that we ever live. The uniqueness of a perfume trace in our memory is an evidence of the importance of olfaction links to our perceptions, emotions and past memories.

Several studies demonstrated that olfactory informations are not elaborated per se, but in synergy with other sensory systems. Castiello et al. (2006) reported that odors drive our hand, modulating and adjusting the hand, to some fruit to grasp. For example, in presence of strawberry odor, the participants prepared their hand to grasp something small, otherwise, in presence of orange odor they prepare their hand to reach and grasp something bigger. Moreover, Seo et al. (2010) demonstrated that olfactory priming effect on visual selective attention. They reported that in presence of an odor the participants look more frequently and longer at a corresponding object (object semantic related with the odor) as compared to the odorless condition.

Furthermore, some studies evidenced how odors drive other kind of processes such as the decision to how allocate money. Bries et al. (2006) showed how in a give-some game, in which the participants had to donate some money to an opponent, the presence of a cue food odor (known to increase the desire to eat) could drive the decision to donate. In particular the results showed that in presence odor of freshly baked brownies the participants donated a lower amount of money to their opponent (compared to the no odor condition). This evidence supports the idea that people are less likely

to sacrifice money (considered as a resource) when they are experiencing the desire to eat something (lack of resources).

The study of olfaction associated with cognitive processes is interesting as well as very difficult, for many reasons. First, the methodological approach at this kind of stimuli is very hard to learn and to manage. Furthermore, some methodological issues make the experiments in the olfaction field difficult in the practice: for example humans actively exert control over olfactory exposure by altering their respiration and attention to olfaction. Moreover in some experimental settings (specifically in between-subject design) is not so clear if the findings are due to the affective reaction induced by the olfactory stimulus, or to the cognitive demand of the task. In addiction, the corpus of studies present in the literature is manly focused on the odor some particular aspects of cognition (e.g., perception, memory and multisensory) and used many different kinds of odor and a lot of methods to disperse them, making difficult compare the new results to the previous ones. For this reason is important try to control all the stimuli, disperse them in the best way and try consciously to avoid all the effect due to the methodological difficulties mentioned above.

Nevertheless, for the same reasons, try to give some demonstrations of the importance of olfactory stimuli in our life is a very interesting challenge.

In this thesis I'll try to give an idea of the relationship between different kinds of odors and decision making processes. In particular, in the first part I'll report an overview of some the most relevant topics on the study of odors, chemosignals and human behavior and their possible relations. Then the aim of the thesis and the empirical studies will be reported. Finally a general discussion of the main findings will be debated.

CHAPTER 1

Odors

Many recent investigations suggested that odors can modulate several processes such as emotional states (Weber et al, 2008; Goel & Grasso, 2004), cognitive processes (Hermans et al., 1998; Heuberger et al., 2001; Millot et al., 2002; Herz, 2004; Lehrner et al., 2005) and behavior (Millot & Brand, 2001). In the follow section I'll try to give a brief overview of the main findings in this field. First, I'll describe the brain areas involved in the odor elaboration in humans. Then, I'll report the main psychological effects due to a pleasant olfactory stimulation. Finally I'll focus on the decision making processes in presence of an odor.

1.1 Neural correlates involved in odors elaboration

Several neuroimage studies have recently been carry out, trying to elucidate the neural pathways involved in the olfactory stimuli elaboration (for a review see Zatorre & Jones-Gotman, 2000, Zatorre, 2002). The main results showed that when an odor is presented to us the orbitofrontal cortex (OFC) is activated, and in particular its right side (Small et al., 1997; Sobel et al., 1998; Savic et al., 2000). This area seems to be involved in the processing of particular features of the odor, such as familiarity (Royet et. al., 1999). Moreover the OFC, in particular the left side, together with the amygdala and other limbic areas, are activated during the unpleasant odor perception (Zatorre et al., 1992).

This evidence suggested first, a role of the amygdala in the affective connotation of the olfactory stimuli, and then a possible lateralization of the hedonic value of an odor. Thus, the separation between the olfactory nerve and the amygdala consists only in two synapses (Herz, 2003). The amygdala is considered crucial for the emotions experience and expression (Aggleton & Young, 2000) and for the memory of emotions mainteniance (Cahill et al., 1995). In addiction, amygdala and OFC together seem to have an essential role in stimulus-reinforced associative learning (Rolls, 1999).

Second, it seems that pleasant odors are mainly elaborate in the right cerebral hemisphere, whilst the unpleasant odors in the left side of the brain. Moreover, the odor exposure significantly increases activity in the posterior piriform cortex (Gottfried et al., 2002; Poellinger et al., 2001; Savic et al., 2000), that is suggested to have a role in the odors classification into categories (Gottfried & Wu, 2009; Li et al., 2008). Different areas are associated

to different kind of task that involve odors, demonstrating that some processes are parallel, whilst others have a hierarchical processing (Savic et al., 2000). For instance, the left insula, and the right cerebellum are engaged in the judgment of odor quality, intensity and familiarity. In addiction to these areas, when the task is to assess if two odors are different or not, the OFC, the caudate and the thalamus are engaged. Furthermore, the hippocampus seems to be specifically involved in higher-level processing of olfactory informations, for example in odor identification (Staubli et al., 1984). The odor identification, that was a task ascribed to the semantic memory, has recently been shown to be the result of an interaction between odor identification, odor memory, semantic memory, and verbalization (Larsson, 1997; Murphy et al., 1991; Perkins & Cook, 1990; Royet et al., 2004). A recent and very interesting study (Kjelvik et al., 2012) confirms that hypothesis and suggest an essential activation of the hippocampus for reactivating episodic memory about odors experienced in the past, necessary for the odor identification (Alvarez & Squire, 1994; Shastri, 2002). Moreover, many evidences showed an activation in areas connected to representation, retrieval, and selection of semantic representations, such as the posterior temporal lobe and inferior frontal gyrus (Badre et al., 2005; Binder et al., 2009; Bookheimer, 2002; Gough et al., 2005; Thompson-Schill et al., 1998; Wig et al., 2005). Thus, the odor identification may not be purely semantic, but also rely on episodic memory (Kjelvik et al., 2012). Finally, the judgment of pleasantness activated the bilateral OFC, the hypothalamus, the right superior frontal gyrus, insula and cerebellum. These regions are engaged in this olfactory task as well as in visual and auditory tasks that involve the emotional evaluation of stimuli. The OFC specifically plays an important role in processes that are related to emotional states. Thus, an activation in OFC is evident during

the presentation of olfactory stimuli with an affective valence (Zald & Pardo, 1997; Blood et al., 1999; Francis et al., 1999).

The findings reported above, highlighted that the olfactory system seems to be the only sensory mechanism that has a direct and unique link to the neural substrates devote to the emotional processing, thus, these evidences indicated that:

> *"The fact that no other sensory sistem make this kind of direct, dynamic contact with the neural substrates for emotion and memory provides strong support for the emotional distinctiveness of olfactory cognition."* (Herz, 2003; p. 171).

In addition, as Zald and Pardo (1997) suggested:

> *" [...] there may well be an important distinction between the neural basis of emotional responses elicited by sensory stimuli such as odors and tastes, and more complex, semantically rich stimuli such as visual scenes. For example, the pleasant emotional response triggered by receiving a bouquet of roses would require a sophisticated analysis of meaning and social information, whereas the pleasant fragrance of a rose can be appreciated through a more direct chemosensory route. The rose's fragrance may trigger additional emotional reactions through associations, but these are not essential for an emotional response to occur. Given their differential origins, it seems reasonable to suppose that the organization of the brain's response in these two cases might also differ substantially."* (Hamann, 2003; p. 107).

1.2 Psychological effects

1.2.1 Mood

A further demonstration of the strong link between odors and emotional states could be find in the human phylogenetic development. Actually, the olfactory structures and the limbic areas, developed together into the most ancient brain part, the rhinencephalon (McLean, 1969). This common origin seems to explain that our capability to experience emotions grew out of the ability to process odors at the cognitive level (Herz, 2003).

As aforementioned, the elaboration of olfactory stimuli is directly linked with the brain areas involved in the emotion and memory processing such as the orbitofrontal cortex (OFC), the amygdala, and the hippocampus (Royet et al., 2003). This link between odor, emotions and emotional memories is very interesting and many studies have examined this association. For instance, Herz et al. (2004) investigated the learning process involve in the perception of odors pleasantness. They stated that an odor is considered pleasant or unpleasant depending on the emotional context in which it was perceived for the first time. Once an association has been created, the odor will tend to act in a consistent manner with the mood: pleasant odors improve mood, whilst, with the unpleasant ones, it gets worst, recreating the emotional state in which they were originally associated. Moreover, Kirk-Smith and colleagues (1983) reported that, the past experience of an ambient odor during a very stressful task could get worst the mood when the participants were re-exposed to the same odor, even if this experience takes place several days later. In addition, some recent studies (Knasko, 1992; Alaoui-Ismaili et al., 1997; Inoue et al., 2003) demonstrated how pleasant odors directly affect mood in the persons exposed to them. In particular, pleasant odors pos-

itively affect the mood and decrease arousal, whereas unpleasant olfactory stimuli tend to negatively affect mood and increase arousal.

1.2.2 Decision making processes

Several empirical studies have shown an interesting link between odors and decision making processes. The association olfactory-emotional processes seem to have an adaptive reason. Actually, in mammals the olfaction informations are the most critical form of communication. In humans, other kind of information transmission, such as vision and verbal communication have the main role. Although, some everyday behaviors are guided by odors. A good example could be the reaction of like or dislike due to smell something. We could consider the approach (i.e., positive reaction to something good or attractive) and avoidance (i.e., negative reaction to something bad or danger) behaviors that follow the odor perception, as well as hedonic or affective responses (Livesey, 1986). For instance, the approach and avoidance behaviors then could drive the decision to choice something to eat, or otherwise to choice something to buy.

The odors, as other peripheral cues, could have an effect on a decision that seems to be not linked to them. The peripheral cues are actually incidental contextual information (e.g., sounds, odors, etc.) not directly related with the decision task. For instance, it seems that a fragrance can trigger emotions that have a consequent action on the individuals' choices (for a review on this topic see Turley & Milliman, 2000). In particular a pleasant odor increases the mood of the person exposed to it, modifying the decision strategies involve in a decision making process.

The literature reports a long list of studies that described the different actions of an ambient scent on consumers' reactions (Bone & Ellen 1999;

Bone & Jantrania 1992; Bosmans 2006; Mitchell et al., 1995; Spangenberg et al., 1996). In particular, Knasko et al. (1990) showed that a pleasant odor dispersed in a store increases the time spent in this ambient, but not the willingness to buy an expensive product such as a jewel. This effect could be ascribed at the conflict between the emotional information (due to the odor) and the rational information (due to the product price). This conflict seems to inhibit the pleasure inducted by the odor exposure.

This study opened a discussion about the kind of odor dispersed in an ambient: the odor pleasantness is very important, but is not the only odor feature that guided the odor effect on the behavior. Thus, a very interesting point is that not just any smell but a smell that is "congruent" with the task could drive the decisions. Mitchell and colleagues (1995) assumed that an odor, pleasant and congruent with the decision to take, will activate a lot of relevant informations to the task and this effect will extend the range of options that people will consider important. This congruent and pleasant odor, then leads to an increase in the variability of consumer choices, promoting the exploration of all existing range of alternatives.

In contrast, a pleasant odor but not congruent with the choice will activate informations not useful to the task. In this case the odor becomes a pleasant distraction that hinders the performance, making the decision process more demanding. It seems that an essential moderator of the odor effects is the congruity between odor and product (Bone & Jantrania, 1992) or between odor and the ambient in which the product is presented (Bone & Ellen, 1999; Mitchell et al., 1995). About this topic, Bone and Ellen (1999) introduced the concept of "diagnosticity". A congruent and pleasant odor has high diagnostic level and drives the consumer to the best choice only if adds information for the decision (e.g., if the odor presence is not predictable). Nevertheless,

the presence of an incongruent odor, even if pleasant, could only make the product evaluation more difficult acting as a sort of disturbing element in the decision process. In this case, actually, the information gave by the odor is not included into the decision domain, and for this reason will act in competition with the decision process. The following cognitive overload could then drive the decisor to focus his attention on some irrelevant information, and finally tend to drive him to a suboptimal decision. Furthermore, the confounding information give by an incongruent odor is to avoid as well as a congruent and pleasant odor too predictable. Odor with "low diagnosticity" traits, doesn't give any additional information to the decision process without any improvement in the product evaluation (compared to the no odor condition).

For these reasons it seems that a positive olfactory stimulus presented in the environment should act as a cue for approaching decisions, evoking some positive emotional states, but only if the odor is congruent with the decisor expectation. Otherwise the presence of an incongruent odor (although pleasant) should aroused negative affective responses, and then tend to lead to a lower level of approaching behavior or to an higher degree of avoidance behavior (Spangenberg et al., 2006).

The evidences reported above showed that the cognitive processes involved in the decision in presence of an odor could be drive not only by the odor features per se, but also by the memories and semantic representations related to it. For instance, Bone and Jantrania (1992) showed an increase in the product quality perception when the product displayed was scented with an odor congruent with the product category (e.g., coconut odor for the sunscreen lotion and lemon odor for a cleaner) compared to the presence of an incongruent odor (e.g., lemon odor for the sunscreen lotion and coconut odor for a cleaner). Furthermore, an interesting study conducted by Spangenberg

et al. (2006) gave support at the congruency hypothesis. The authors reported that a pleasant odor dispersed in a retail store could have an impact on the decision to buy something, in relation with the congruency between odor sexual connotation an product sexual connotation (e.g., gender-based products such as male or female clothes). In particular they found that when odor and product sexual connotation were congruent (i.e., rose maroc for men's clothing, and vanilla for women's clothing) the participants spent more time in the store, purchased more items and spent a larger amount of money, compared to the incongruent condition where the scent's gender orientation did not correspond with the product offered (i.e., rose maroc for women's clothing and vanilla for men's clothing). Moreover the participants expressed a stronger intentions to visit the store in the future when exposed to the congruent condition (compared to the incongruent condition).

Prosocial decisions

In the last thirty years a lot of studies have shown a strong relationship between positive affects and prosocial behaviors. It seems that a positive mood could mediate a lot of behaviors making people more generous, more helpful to the others and more interpersonal understanding (e.g., Aderman, 1972; Cunningham, 1979; Cunningham et al., 1980; Isen, 1970; Isen & Levin, 1972). For instance, in a famous series of studies conducted from the Seventies the participants who were unexpected offered a cookie, donated more to good causes, were more glad to help someone in carrying several books, and were more willing to help a passerby who dropped a folder of papers, and so forth (see, Isen, 1970; Isen & Levin 1972; Isen, 1987; Isen 2001; Isen, 2008).

In many studies the experimenters have induced an incidental positive affect in the participants. They inducted a positive mood giving a little gift

or something to eat (e.g., a cookie or candies) to the participants, or finally, showing happy faces or comical movies. Mellers et al. (2010) reported that participant in which they inducted a positive mood (e.g., giving a candy bag or seeing a comedy routine) showed more altruism in an economical game such as a Dictator game (i.e., a classical economic games that measures altruism). They explained this change in Dictators self-interest with a sort of mediation caused by the induction of an incidental positive mood. In particular the authors assessed that a positive mood could lead a shift in a prosocial behavior and consequently the participants tended to consider the other happiness more enjoyable.

As aforementioned, pleasure odors could also trigger positive affect states. Many studies reported that a fragrance could elicit a positive mood that has a consequent action on the individuals' choices (for a review on this topic see Turley & Milliman, 2000). In particular a pleasant odor increases the mood in persons expose to it modifying the choice strategies involve in a decision make process and then changing the final choice. In the prosocial domain, Bries et al. (2006) showed how in a give-some game, in which the participants had to donate some money to an opponent, the presence of a cue food odor (i.e., odor of freshly baking cookie, known to increase the desire to eat) could drive the decision to donate. In particular the results showed that in presence of the pleasant odor of freshly baking brownies the participants donated a lower amount of money to their opponent (compared to the no odor condition). This result suggest that people are less likely to sacrifice their economic resources in presence of an odor that elicit in them the desire of food. Moreover, a famous 2010 study by Liljenquist and collegues used the lemon fragrance, that is usually associated with the ideas of soap, freshness. In presence of the lemon fragrance people change their decisions showing

more moral choices than in non-odor condition. This result may state that the lemon odor would activate the concepts of cleanness and purity, which could be extended to other contexts such as decision-making ones.

CHAPTER 2

Chemosignals

The scientific debate is focused from several years on the concern of the pheromones existence in humans. These compounds exist in animals and have an action on many of their behaviors. From the sixties a lot of research tried to claim if the androstenes, a class of steroid molecules that constitute the phermones and present in humans, have or have not all the characteristics of the animal pheromones or affect humans in the same ways in which they affect animals. Thus, in humans the pheromones existence is nowadays an unresolved question. For instance, Doty (2010) strongly refuted the possibility of pheromone presence in humans and look at these compounds such as odors with a social function, as chemical signals. For this reason the term "pheromone" is used with prudence in the human domain liking better the term "chemosignal", and leaving the classical pheromone definition for the animals.

In the follow section I'll try to give a brief overview of the main findings in the chemosignals field. First, I'll describe the chemosignals and where they are produced and elaborated in humans. Then, I'll report the main psychophysiological effects due to the exposure to androstadienone, a chemosignal that we decide to use in our empirical studies.

2.1 Chemosignaling in humans

The pheromones are a very interesting and controversial field of studies. The attention on them is year by year increasing because many evidences gave them a crucial role in the communication into the same species. The original definition of pheromone was proposed by Karlson and Luscher (1959) and assesses that pheromones are not only substances present on the body, but also they are:

> *"substances [...] perceived by a second individual of the same species in which a specific response is induced, for example a specific form of behavior or process of development".*

This definition was then specify, distinguishing the pheromones into two categories: the *releasers*, which should immediately elicit a behavioral response upon reception, and the *primers*, which caused physiological changes, resulted into long-lasting and slower changes. The primers influence endocrine states and development, that ultimately lead to behavioral changes (McClintock, 2000). These social signals seem to be responsible for the communication of a series of information between individuals of the same species: sexual attraction, mating compatibility, presence of danger and alarm behavior, presence of food and directions for the more efficient route to reach it, kin recognition, recruitment, and so on (Johnston, 1998; Lundström et

al., 2009; Porter et al., 1985; Potts et al., 1991; Stowe et al., 1995). More recently, a new specification was proposed taking into account not only the resulting changes due to the pheromones communication, but the kind of information transmitted by the substances. In particular, the pheromones was divided into *signallers* and *modulators*. The signallers transmit informations about the sender and the modulators influence the mood and the cognitive processes (cfr., Marazziti et al., 2009; Brennan & Zufall, 2006; Ngai, 2006; Sheperd, 2006). Actually, the modulators are thought to be present and to act mainly in humans and specifically in the interplay with their social surrounding (Lundström, 2005b). The modulators have been definited by McClintock (2003) as:

> *"Modulator pheromones modulate outgoing behavior or a psychological reaction to a particular context, without triggering a specific behavior or thoughts. They change stimulus sensivity, salience and sensory-motor integration".*

In humans the chemosignals are mainly produced by the apocrine glands in the axillae and pubic regions and by the ovaries (Smals & Weusten, 1991), and their metabolism follows the pathway of steroid production (steroidogenic; Dufort at al., 2001). These structures start to have a function in the puberty. Thus, at this point in time, that is commonly considered the starting of the sexual maturation, the apocrine glands begin to produce some steroids, the androstenes (16-androstene steroids), via testosterone with an higher concentration in males, compared to females (Brooksbank et al., 1972; Gower & Ruparelia, 1993). Actually, the sexual and age differences in the androstenes production are crucial to understand their function. For instance, maybe the androstenes production, in relation to puberty, could be an important information for the sexual maturation and could influence in some ways

the sexual attraction and the partner selection (Andersson, 1986). The androstenes (i.e., androstenone, androstenol, androstadienone) present on the body are not perceived as having a particular odor, but the exposure to them is demonstrated to have an influence on some psychophysiological parameters. Thus, only the supersmellers, defined as persons that are able to detect a chemosignal (e.g., androstadienone) at low concentrations as an odorant (i.e., when is not in solution with other masking odors). With regard to this, Lundström (2005b) demonstrated that the lowest concentration of androstadienone detected by supersmellers is 76μM, and the absolute threshold in the population (supersmellers included) for the androstadienone detection is 211μM. If the supersmellers are excluded, the absolute threshold in the population increases to 300μM.

The most studied chemosignals up-to-now are 4,16 androstadien-3-one (androstadienone, AND), derived from testosterone and secreted in a concentrations up to twenty times higher in men, compared to women (Marazziti et al., 2009) and estra-1,3,5(10)16-tetraen-3-olo (EST) a substance resembling the estrogens (Gower & Ruparelia, 1993; Monti-Block & Grosser, 1991; Sobel et al., 1999), known as the primary female sex hormones. Frasnelli et al. (2011) stated that:

> *"The endogenous odorant that has been singled out as the most likely candidate to be a human chemosignal is the closely related steroid androstadienone (AND)."*

Furthermore, AND was proposed as a human pheromone by Sobel and Brown (2001). The function of AND could be ascribed to a modulator pheromone.

2.1.1 Structures and neural correlates involved in chemosignals elaboration

An outgoing controversial regards not only the existence of the chemosignal (or pheromone) communication in humans, but the elaboration of these compounds. Nowadays is not clear where the chemosignals are processed in humans . It was long assumed that the pheromones were processed in the vomeronasal organ (VNO), a region of the main olfactory system, also referred to as *Jacobson's organ*, responsible for the pheromone detection in mammals.

The VNO structure in humans is located in the nasal cavity (Meredith, 1991; Wysocky, 1979) and in particular, in the anterior third of the epithelium in the nasal septum (Jacob et al., 2000; Knecht et al., 2001). VNO seems to be vestigial in some primates and about this, Yoon et al. (2005) reported that in mice the VNO is not responsible for the recognition of a kind of pheromone, mainly ascribed to the mating behavior. Thus, this pheromone is processed by the olfactory epithelium. If the doubt about the VNO action in the animal domain are starting to be discussed, in the humans many hypotheses about its function have been investigated. Interestingly, Monti-Block and Grosser (1991) study reported an electrical response in the VNO when was stimulated by a chemosignal (androstadienone). However, many other evidences are against the function of VNO in humans (Meredith, 2001; Trotier et al., 2000; Witt et al., 2002). Moreover, in a recent study, Frasnelli and colleagues (2011) provided support against the involvement of VNO in the chemosignal elaboration. The authors conducted three experiments and they found no differences in the androstadienone perception (i.e., change in threshold as well as change in intensity and pleasantness ratings and change patterns of brain activation after odor stimulation) in case of VNO occlusion (compared

to the condition in which the VNO was in its normal status). These results confirm the findings of a previous study in which, instead of androstadienone, was used an other kind of chemosignal, androstenone (Knecht et al, 2003). Furthermore, Rodriguez et al. (2000) proposed that a vomeronasal receptor gene, that in rodents is located in the VNO, in humans is expressed in the olfactory mucosa. These findings suggest that VNO seems to be not involved in the elaboration of chemosignals in humans. For these accounts, it seems to be reasonable to think that this type of odors are processed via the main olfactory system.

A further field of studies is aimed to give rise to different brain activations in chemosignals elaboration, compared to odors (Jacob et al., 2001b; Savic et al., 2001; Gulyas et al., 2004; Savic et al., 2005; Berglund et al., 2006). In particular, Jacob et al. (2001b) showed, in women exposed to androstadienone in clove oil, brain activation in prefrontal cortex, amygdala and hypothalamus. Moreover, Savic and colleagues (2001) reported the activation of some brain areas, that seems to be sexually dimorphic and involved in sexual orientation, and more generally, in sexual behavior (cfr., Havlicek et al., 2010). Their interesting findings showed a sexually specific brain activation for two chemosignals: AND and EST. Thus, the same region, the anterior-ventral part of hypothalamus, was activated in women exposed to AND as well as in men exposed to EST. In addiction, Savic et al. (2001) showed that AND and EST activated areas involved in the odor elaboration, such as amygdala, insula, piriform cortex and orbitofrontal cortex. Interestingly, the regions activated after the AND inhalation in heterosexual women were similar in the homosexual men (Savic et al., 2005), but not in homosexual women (Berglund et al., 2006) Furthermore, Gulyas et al. (2004) PET (positron emission tomography) study was aimed to compare the brain activations due

to the olfactory experiences of a chemosignal (AND in dipropylene glycol), two odors (pleasant and unpleasant) and a control (no odor). The areas involved in AND condition compared to the control were the orbitofrontal cortex, the inferior prefrontal cortex and fusiform gyrus. The activations in AND condition compared to the two odors conditions were localized in the inferior prefrontal cortex, and superior temporal cortex. These two areas are very important in social interaction and attention. With regard to this, Havlicek et al. (2010) stated that:

> *"[...] the inferior prefrontal cortex is know to be involved in face recognition and in mental states connected with social interaction. The inferior prefrontal cortex is activated in social cognitive and emotional processes. Thus, these activational patterns emphasize the potential role of androstenes in social interactions."*

Moreover, is demonstrated by Lundström et al. (2006a) that the cerebral processing of AND is more fast than the processing of other odorants, and the sensitivity to AND in women is higher in the fertile period of the menstrual cycle (compared to the luteal phase). As the authors suggested, these evidences were linked to the assumption of a crucial and functional role of AND in the mate choice (Jacob & McClintock, 2000; Lundström et al., 2003a,b; Savic et al., 2001; Saxton et al., 2008). With regard to this, Cornwell et al. (2004), reported an effect of AND on the partner choice. In particular, they found a significant correlation between the odor evaluation of AND for pleasantness and their preference for a stereotypical masculine face as a longtime partner. This result not only open the discussion on the odor perception of AND that is nowadays controversial, but highlighted the role of AND as a human chemosignal. AND seems to have an action in guiding social and sexual behavior, similar to what occurs in the animals.

2.1.2 Physiological and psychological effects of androstadienone

Several studies were conducted to assess the psycho-physiological effect of exposure to androstenes. In this section I'll report a brief review of the main effects of androstadienone. Many of these are sex-dependent.

For instance, Jacob and colleagues (2001a) showed in women exposed to AND an increase in skin conductance and a decrease of skin temperature, whilst in men only a decrease in skin temperature. These interesting results are even more relevant if we consider the experimental setting used. Thus, the AND effects reported were more strong when the experimenter was male, in case of female participants, otherwise, if the participants were males, there was no effect of the experimenter's gender. Moreover, Grosser et al. (2000) showed that the AND injected directly into the VNO causes in women a significant reduction in emotional states of negative connotations, like for instance, nervousness, boredom and frustration, and leads to accelerated physiological levels of pre-ovulatory hormone production (luteinizing hormone, LH), to decrease respiratory frequency and heart rate, to reduce the psycho-galvanic response and to increase the alpha cortical activity and body temperature.

The chemosignals, as well as the odors, are studied as moderators of affective states. Thus, several studies were focused on mood. Some of these showed that in women exposed to AND, there is an improvement in mood states (Jacob & McClintock, 2000; Jacob et al., 2002; Lundström & Olsson, 2005), whilst in men a trend to worsening their mood or to keep the mood reported in an earlier stimulation period (Jacob & McClintock, 2000; Bensafi et al., 2004a,b; Villemure & Bushnell, 2007). Moreover, women exposed to AND in eugenol (a clove like odor) reported to feel themselves more focused

(Lundström et al., 2003a) and resulted more tolerant to pain (Villemure & Bushnell, 2007). Heterosexual women also showed an increase in mood and in arousal, but only if the experimenter was of the opposite sex (experimenter gender effect; Lundström & Olsson, 2005) and was present throughout the study (Hummer & McClintock, 2009). Moreover, men exposed to AND showed a increase in positive mood only if the experimenter was a female (Jacob et al., 2002). The effects of AND exposure on emotional states seems to be dosage and context dependent. Bensafi et al. (2004b) found that the chemosignal dosage is a crucial variable to induce psycho-physiological changes. In particular they reported changes in mood with an high concentration (650μM), not highlighted in presence of AND at low concentration (250μM). It is noteworthy that, the low concentration used by Bensafi et al. (2004b), 250μM, is the most used concentration of AND in the studies on chemosignals. In particular, they found an increase in positive mood and a decrease in negative mood only in female exposed to AND in high concentration. Furthermore, the same research group (Bensafi et al., 2004a) used neutral, sad, happy or erotic movies in presence of AND. The result showed in presence of AND an increase in positive mood only in female and associated with sad movies, and an increase in both gender arousal associated with erotic movies (no effects were found with neutral and happy movies conditions). An other study on the contextual effects of AND was proposed by Hummer and McClintock (2009) and reported the effects of AND on attention and perception. In particular, they found in both men and women a faster attentional response to emotional stimuli (affective facial expressions) compared to neutral stimuli or shapes. Moreover, the results showed an effect of AND in the Stroop test, only if the stimuli were emotional words (compared to neutral stimuli). In a different setting from the laboratory, Saxton

et al. (2008) conducted an elegant study. They used in an ecological context like a speed-dating (a series of interaction with potential partners with time pressure) to examine the effect of AND presence on ratings of attraction of potential partners. The results showed that women exposed to AND in clove oil, tended to rate as more attractive the men that met during the speed dating (compared to the women exposed to clove oil alone).

In the decision making field the only study that involved chemosignals was conducted by Ebster and Kirk-Smith (2005). The aim of the experiment was to examine the effect of an androstene (i.e., androstenol) in the marketing context and in particular, in product evaluation. The results showed in men an evaluation of the product (i.e., rating three magazines as masculine, neutral or feminine) as more masculine. Moreover, men had more positive buy intentions in presence of androstenol diluted in ethanol (compared to the control condition with ethanol alone). In women no differences were found between chemosignal and control condition.
In conclusion, the studies reported above indicated an engagement in chemosignals elaboration of areas involved in the odor perception and moreover of other areas linked to social interaction and sexual behavior .

Furthermore the activation patterns were dependent on gender and sexual orientation. These evidences suggested an involvement of chemosignals, and in particular AND and EST, as important social and sexual behavior moderators, not only in animals. Indeed, AND and EST modulate human behaviors to some degree and in a faster way than other odors. However, these results are controversial, and suggest us to be aware of several details such as the choice of the right compound, its concentration and the participants' gender.

CHAPTER 3

Aim of the thesis

As aforementioned, there are many evidences that odors and chemosignals have an effect on a wide range of human behaviors. However, as reviewed above, the question of whether they have effects on altruistic behavior has not been addressed. Moreover, the effect of odorants on mood is not clear. Specifically, it seems that pleasant odors have not an effect on mood, but is largely demonstrated that chemosignals can modify the mood in persons expose to them.

The fundamental aim of this thesis was to explore whether pleasant odors and a specific chemosignal, androstadienone, function as mediators in decision-making processes that involve altruism.

To examine this question this work is divided into two parts: the first about odors and altruism toward things (public goods evaluation), the second about chemosignals and altruism toward persons (economic games such as

dictator game and trust game).

This general question was then subdivided into (seven) more specific research questions:

i. Do ambient odors have an influence on value attribution and the decision to donate?

We choose to respond to this question in a particular context: the ambient public good evaluation. There are two reasons: first, the public goods haven't a predeterminate value. Consequently the persons are free to decide their value subjectively and then how much donate. Moreover, we can associate some ambient public goods with specific odors. In this way we can examine the effect of this association (i.e, congruity between odors and public goods). Finally, we can examine this effect using scenarios by which the participants are supposed to donate an amount of money (hypothetical decision) or to donate real money (real decision).

ii. What are the previously found effects due to?

One hypothesis is that these effect are due to a preferential concept activation. In particular, some odors could directly activate concept related to it and in this way make some concept more available than others. Moreover, is possible that this sort of facilitation could be extended to other cognitive processes. To verify this assumption we run an experiment on word recognition.

iii. Does the sensorial modality have an effect on the congruity effects that we found?

We tested the "congruity hypothesis" changing the sensorial modality of the presented stimuli (odors and images).

iv. We found some interesting effects of odors on decision making. Is it possible to extend the effect of odors in different donation domains?

To respond to this question we decided to use chemosignals as the odor more congruent with people, hence to donations toward people. Specifically, we use androstadienone to examine the effects of an human endogenous odor on the decision to donate (in form of a Dictator Game) and to trust (with a Trust Game) others.

v. Are the findings due to the chemosignal dosage?

This question should be an important aspect of study on the effect of chemosignals in humans. Bensafi et al., 2004b reported changing in the awareness to chemosignals and in some psychological and physiological variables due to the odor concentration. Maybe this parameter could be central for the decision making processes too.

vi. Are the findings driven by a mood effect?

A series of studies (Bensafi et al., 2004 a,b) showed how the androstadienone affects mood states depending on its concentration, the participants' gender and other parameters. It is possible that a mood change due to a chemosignal (compared to other possible mood induction) could change the decision to donate.

vii. Is the dosage responsible for changing in the decision to donate in a Dictator Game?

As aforementioned, the androstadienone dosage is responsible for many psychological and physiological effects (for a review see Havlicek et al, 2010). We modulate the chemosignal concentration to see if this particular kind of odor could elicit different decision responses.

These specific aims will be analyze in more detail in four different papers, presented below.

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Part II

Empirical studies

CHAPTER 4

Paper I - Incidental scents and evaluation of environmental goods

4.1 Abstract

We examined whether the semantic congruency between an ambient odor and a target public good influences the willingness to contribute and to pay for hypothetical (Experiment 1) and real money donations (Experiment 2). The results supported this prediction, in both experiments participants donate more in case of presence of an ambient odor related/congruent with the public action (e.g., lemon fragrance and lemon garden reintegration).

We confronted three possible explanations: mood-based, symbolic-based and semantic based account. Our results support the semantic-based account that we explain in terms of "accessibility": the congruency between odor and public good could be a cue for the mental accessibility of the notion of "lemon

trees" that induces people to contribute more for a lemon-tree reforestation plan.

Keywords: ambient odor, fragrance, olfaction, public good, generosity

4.2 Introduction

Marketing practices draw upon a presumed effect of ambient scent on emotion, cognition and behavior (see Turley & Milliman, 2000 on atmospherics; Bone & Ellen, 1999 for a review on olfactory effects). For example, Sony Corporation diffuses a mixed fragrance of vanilla and mandarin in its 36 boutiques that are scattered around the world (press reports, Gaggi, Corriere della Sera, October 3, 2006, p. 4). During a concert of Jovanotti, a famous Italian pop star, fragrances were dispersed that were thematically related to various songs. For example, when he performed "Per Te", a song dedicated to his newly born daughter, talcum powder aroma was diffused in the air (press reports, Luzzatto Fegiz, Corriere della Sera, November 7, 1999, p. 35).

But is there any scientific basis for these practices? Scientific literature suggests that there is, and several accounts have been proposed.

Mood-based accounts. Accounts nested within this category suggest that odors influence evaluation and behavior through mood arousal or mood valence. In their extensive review, Bone and Ellen (1999) found mixed results regarding the effect of odor on mood arousal, but empirical support for an effect of scent pleasantness on mood valence. Similarly, Guèguen and Petr (2006) reported that a pleasant odor (lavender) induced customers to spend more time and money in a restaurant. These authors suggested that the behavior was influenced by the relaxing effect induced by lavender. In addi-

tion, Li, Moallem, Paller and Gottfried (2007) found that neutral faces were evaluated as more likeable under a subliminal pleasant odor than under a neutral or unpleasant odor.

Symbolic-based accounts. Recent investigations on implicit priming on social preference support that a symbolic value or social norm (morally sound behavior) can be activated by subtle peripheral cues, such as olfactory (Liljenquist, Zhong & Galinsky, 2010) but also visual (Shariff & Norenzayan, 2011). Liljenquist et al. (2010), for example, argued that clean scents promote virtuous behavior via a symbolic activation of the concept of moral cleanness. They reported that a lemon-scented room led participants to reciprocate more, and be more charitable. Like the mood-based accounts, this account posits a main effect of odor on evaluation and behavior. A clean scent (e.g. a lemon fragrance) should activate (per se) the concept of morality and should have a positive effect, regardless of the type of public cause.

Semantic-based accounts. These accounts hold that a scent can have enhancing or detrimental effects on behavior or choice, depending on its congruity with a target object (see Bone & Ellen, 1999 for a discussion of the congruity effect; Rossi et al., 2008 and Castiello et al., 2006 for cross-modal interactions between olfaction and grasping). Focusing on preferences, which are the object of our study, Bone and Jantrania (1992) found that participants evaluated more positively a particular class of products (e.g., suntan lotion) under a congruent ambient odor rather than under an incongruent or neutral odor.

With two experiments we aimed to extend the context-congruency hypothesis to the evaluation of public goods, such as willingness to contribute (WTC) and willingness to pay (WTP) for a reforestation project. The study of the estimated value of a public good helps to understand how people ex-

press (in monetary terms) their affective evaluations toward an object (Kahneman, Ritov & Schkade, 1999) and it is relevant also from the economic point of view.

The basic experimental design involved crossing two public goods (reforestation project of either lemon or pine trees) with three odor conditions (lemon vs. pine vs. neutral). We expect that congruent odors will increase willingness to support an environmental public good, with respect to incongruent or neutral odors (congruency hypothesis). To our knowledge, this is the first study of its kind. Note that in contrast to Bone and Jantrania's (1992) study where odor was a feature of the proposed product, in the present studies the odor is not a quality-cue of the proposed public action. The expected benefits (and costs) associated to the public action are the same across odor conditions and, from standard economic theory, preference should not be affected. In the Discussion we will address competing explanations of reported findings.

4.3 Experiment 1

Two clean odors (lemon and pine) were selected on the basis of a pilot study in which participated six males and six females. The fragrances were evaluated using the Labeled Magnitude Scale (LMS, Green et al., 1996) and were judged similar in terms of intensity, pleasantness, unpleasantness and familiarity. The environmental public goods were the Garda lemon-gardens and the Adamello-Brenta Park. For both goods, the scenario referred to an environmental hazard (e.g. a parasite attack) and a public action aiming to fix it (e.g. a reforestation plan). In both scenarios, participants were first asked whether they were willing to contribute (WTC) for the public action

(e.g. pine-tree reforestation; lemon-tree reintegration), and, in case of an affirmative response, how much they were willing to pay (WTP). The suggested contribution was 10 euro. A sample of 188 foreign students participated in the study (59.6% males). They reported normal ability to smell. The participants were randomly assigned to one of three congruency conditions, with each participant evaluating a single problem. In the congruent condition, participants evaluated a problem under a congruent ambient odor (lemon odor–lemon-tree reforestation or pine odor–pine-tree reforestation). In the incongruent condition, participants evaluated a problem under an incongruent ambient odor (lemon odor–pine-tree reforestation or pine odor–lemon-tree reforestation). Fragrances were dispersed in a pre-aerated room; the quantity of the fragrance was held constant between conditions. We also used a control condition where the two target problems were evaluated in the same room where no specific odor was dispersed.

To rule out mood as a driver of the effects of type of odor, participants were asked to fill a mood scale composed of eight items, adapted from Ehrlichman and Bastone (1992). The Cronbach's Alpha indicated a good level of reliability of the scale's items ($\alpha = 0.71$), so we calculated a mood index by taking the mean value across the scales. An ANOVA showed that the mood index is not affected by the ambient odor: F (2, 185) = 1.72, p = .18. The mean (SD) mood index for the participants that smelled lemon, pine or nothing (control) were respectively: 0.89 (0.72), 0.62 (0.97) and 0.81 (0.77).

We also measured the activation of the concept of cleanness, by asking participants how clean they thought the lab room was (1-7 scale). There was no difference between the pine scent (N = 60) and lemon scent (N = 68) conditions (M = 5.58 vs. M=5.57; t(126) = 0.052, p = .959). In addition, we asked participants to report the extent to which they believed the cleanness

of the room influenced their answers on a 1-7 scale: 1 = "Not at all", 7 = "Very much". Across the two odor conditions the scores were significantly lower than 4 (the central value of the scale): M = 2.3, SD = 1.6; t(127) = -12.4, p < .001. Overall the pine and lemon odors were equally effective in activating the concept of cleanness and the participants believed that the factor "environmental cleanness" did not affect their choices.

Finally, participants did not seem aware of the odors, only 10.6% stated that they felt a particular odor, and this perception was not influenced by odor condition (χ^2 (2, N=188) = 1.77; p = .412).

4.3.1 Results

Table 4.1 reports WTC and WTP for the two public goods. In the overall analysis we considered the effect of congruency between odor and public good without distinguishing between the two public goods.

A logistic regression showed a congruency effect on WTC (Wald χ^2 (2) = 6.89; p = .032). Participants were more WTC in the congruent vs. control condition (76.7% vs. 55%; Wald χ^2 (1) = 6.88; p = .009). The difference between the WTC in the incongruent vs. control conditions was not significant (63.2% vs. 55%; Wald χ^2 (2) = 1.29; p = .256). In addition, the analyses showed that the better the mood, the higher the WTC (β = 0.58; Wald χ^2 (1) = 7.91; p = .005). The perception of cleanness of the room did not affect WTC (Wald χ^2 (1) = 1.31; p = .252).

We ran an ANCOVA analysis on WTP evaluations, using mood index and cleanness perception as covariates. WTP were winsorized at 50€(two standard deviations above the mean). Controlling for mood and cleanness perception, congruency had a marginally significant effect (F(2, 183) = 2.99; p = .053).

A contrast analysis showed that WTP was higher in the congruent vs. control condition (M=14.4 vs. M=8.27, p = .015); WTP did not differ between the incongruent and control conditions (M=11.1 vs. M=8.27, p = .247). The covariate factor mood was statistically significant: F (1, 183) = 21.14; p < .001, while cleanness perception was not: F (1, 183) = 0.26; p = .608.

We then repeated these logistic regressions for each public good separately.

Garda lemon gardens				
WTC	Odor-Problem Congruency			Total
	Control	Incongruent	Congruent	
Yes	19 (50%)	19 (63.3%)	25 (83.3%)	63 (64.3%)
No	19 (50%)	11 (36.7%)	5 (16.7%)	35 (35.7%)
Total	38 (100%)	30 (100%)	30 (100%)	98 (100%)
Mean WTP (SD)	6.97 (10.5)	7.23 (10.1)	15.6 (15.4)	9.7 (12.6)
Adamello Brenta park				
WTC	Odor-Problem Congruency			Total
	Control	Incongruent	Congruent	
Yes	14 (63.6%)	24 (63.2%)	21 (70%)	59 (65.6%)
No	8 (36.4%)	14 (36.8%)	9 (30%)	31 (34.4%)
Total	22 (100%)	38 (100%)	30 (100%)	90 (100%)
Mean WTP (SD)	11.14 (14.8)	13.55 (16.8)	13.47 (16.8)	12.93 (16.2)

Table 4.1: WTC (%) and mean WTP (SD) for the two separate public goods.

Garda lemon-gardens

WTC evaluations were strongly affected by congruency (Wald χ^2 (2) = 7.88; p = .019). As expected, participants were more willing to contribute in the congruent vs. control condition (83.3% vs. 50%; Wald χ^2 (1) = 7.60; p

= .006). WTC in the incongruent vs. control conditions was not significant (63.3% vs. 50%; Wald χ^2 (2) = 2.23; p = .131). We also found that the better the mood, the higher the WTC (β = 0.65; Wald χ^2 (1) = 4.34; p = .037). The perception of room cleanness did not affect the WTC (Wald χ^2 (1) = 0.20; p = .657).

Further support to the congruency hypothesis comes from an ANCOVA analysis on WTP evaluations (winsorized at 50€), using mood index and cleanness perception as covariates. Controlling for mood and cleanness perception, congruency continued to have a significant effect (F(2, 93) = 4.87; p = .010).

Again, WTP was higher in the congruent vs. control condition (M=15.6 vs. M=6.97, p = .003); WTP did not differ between the incongruent and control conditions (M=7.23 vs. M=6.97, p = .596). The covariate factor mood was statistically significant: F (1, 93) = 4.83; p = .030, while the perception of room cleanness did not affect the WTP: F (1, 93) = 0.66; p = .419.

Adamello Brenta park

WTC for the Adamello-Brenta park was not affected by congruency (Wald χ^2 (2) = 0.80; p = .670). In all three conditions, WTC was over 60% (63.6%, 63.2% and 70%, respectively). Mood affects WTC (β = 0.55; Wald χ^2 (1) = 3.81; p = .051). The perception of room cleanness did not affect the WTC (Wald χ^2 (1) = 1.67; p = .197).

A similar result is found on WTP evaluations in an ANCOVA analysis using mood index and cleanness perception as covariates: M=11.1, M=13.6, M=13.5; F(2; 85) = 0.13; p = .882. The covariate factor mood was statistically significant: F (1, 85) = 13.92; p < .001, while the perception of room

cleanness was not: F (1, 85) = 0.03; p = .857.

The above finding could be due to a ceiling effect caused by the popularity and perceived importance of the National Park. In support of this, perceived importance ratings were higher for Adamello Brenta park vs. the Garda lemon-gardens (M=5.48 vs. M=4.81; t(186) = 3.178; p = .002).

Experiment 1 asked for WTC and WTP, which measure intentions to support an environmental public cause. Since the importance of real money incentives and contributions has been discussed at length (see Camerer & Hogart, 1999 for a review), especially in regard to the public goods evaluation (Neill et al., 1994) in Experiment 2 we measured real money contributions.

4.4 Experiment 2

This Experiment was similar to Experiment 1, with two main exceptions. First, participants were asked for real money contributions. Second, we dropped the control conditions. Specifically, each participant received 8 euro as a participation fee, and anonymously decided if and how much of the 8 euro to donate in favor of a target public good.

The participants (N = 153) were employees of the municipality of Trento. The participants were randomly assigned to one of two conditions: congruent or incongruent. Again, to rule out the mood as a driver of the effects of type of odor, participants were asked to rate mood scales. In addition, to control for arousal level, this time we used three clusters of mood ratings following Ekman, Freisen and Ancoli (1980). As proposed by Bensafi et al. 2004, the mood scales were classified in three clusters: positive mood, high arousal negative mood and low arousal negative mood. One participant did not complete the task and thus was excluded from the analyses. The mean

mood values of the three clusters were not affected by the ambient odor: t(75) = 0.5; p = .62; t(75) = -1.18; p = .24 and t(75) = -1.35; p = .18, respectively.

4.4.1 Results

Table 4.2 reports WTC (%) and Donations[1] (SD) for the two public goods.

As in Experiment 1, we run an overall analysis followed by separate analyses for each public good. In the overall analysis, a logistic regression showed that participants were more willing to contribute in the congruent vs. control condition (98.5% vs. 89.7%; Wald χ^2 (1) = 3.63; p = .057). The three mood measures (positive, negative high arousal and negative low arousal) did not affect WTC choices (Wald χ^2 (1) = 0.60; p = .437; Wald χ^2 (1) = 0.00; p = .949 and Wald χ^2 (1) = 0.48; p = .487, respectively).

We run an ANCOVA analysis on WTP evaluations, using the mood indexes as covariates. Congruency did not affect WTP: F(1, 146) = 1.04; p = .308. The covariate factors positive mood and negative mood-low arousal were not statistically significant: F (1, 146) = 0.82; p = .368 and F (1, 146) = 3.12; p = .079, respectively. On the contrary, the covariate negative mood-high arousal was significant: F (1, 146) = 5.17; p = .024.

We also ran two separate logistic regressions, one for each problem.

Garda lemon-gardens

As expected, participants were more willing to contribute for the same cause in the congruent than in the incongruent odor condition (100% vs. 85.4%; χ^2(1, N=78) = 3.99; p = .046.

[1]The term "Donations" indicates that people actually donated some money for the public goods.

Garda lemon gardens			
WTC	Odor-Problem Congruency		Total
	Incongruent	Congruent	
Yes	35 (85.4%)	37 (100%)	72 (92.3%)
No	6 (14.6%)	0 (0%)	6 (7.7%)
Total	41 (100%)	37 (100%)	78 (100%)
Mean WTP (SD)	4.80 (3.2)	5.68 (2.5)	5.22 (2.9)
Adamello Brenta park			
WTC	Odor-Problem Congruency		Total
	Incongruent	Congruent	
Yes	43 (93.5%)	28 (96.6%)	71 (94.7%)
No	3 (6.5%)	1 (3.4%)	4 (5.3%)
Total	46 (100%)	29 (100%)	75 (100%)
Mean WTP (SD)	5.51 (2.7)	5.50 (2.6)	5.51 (2.6)

Table 4.2: WTC (%) and mean WTP (SD) for the two separate public goods.

For this analysis we calculated a Chi-square test with continuity correction and not a logistic regression because one cell of the table has a frequency of zero). The three mood measures (positive, negative high arousal and negative low arousal) did not affect the WTC (Wald χ^2 (1) = 1.69; p = .681; Wald χ^2 (1) = 0.05; p = .821 and Wald χ^2 (1) = 0.00; p = .950, respectively).

An ANCOVA analysis on WTP evaluations indicates that the amount donated in the congruent condition was higher to that in the incongruent condition, though not significantly (M=5.69 vs. M=4.72; F(1, 72) = 2.47; p = .120). The covariate factors positive mood and negative mood-low arousal were not statistically significant (F (1, 72) = 0.88; p = .352 and F (1, 72) = 2.14; p = .148). The covariate factor negative mood-high arousal was

statistically significant (F (1, 72) = 4.29; p = .042).

Adamello Brenta park

WTC for the Adamello-Brenta park was not affected by congruency (96.6% vs. 93.5%; Wald χ^2 (1) = 0.06; p = .799). The three mood measures (positive, negative-high arousal and negative-low arousal) did not affect the WTC (Wald χ^2 (1) = 1.11; p = .291; Wald χ^2 (1) = 0.43; p = .513 and Wald χ^2 (1) = 0.14; p = .706, respectively).

An ANCOVA analysis on WTP evaluations indicates that the amount donated in two conditions was not significantly different (M=5.50 vs. M=5.63; (F(1, 69) = 0.04; p = .848). The covariate factors positive mood, negative mood-low arousal and negative mood-high arousal were not statistically significant (F (1, 69) = 0.29; p = .590; F (1, 72) = 1.29; p = .260 and F (1, 69) = 1.19; p = .280).

4.5 Discussion

Two experiments demonstrated that congruent ambient odors increase both stated and actual contributions for a public cause, as compared to incongruent or neutral ambient odors.

The reported congruency effect cannot be accounted by differences in mood across conditions, because the participants' mood was not affected by odor condition. Also, when controlling for mood, congruence still exerted a significant influence. This finding is similar to that reported by Liljenquist et al. (2010) who found that the effect of a clean scent on prosocial behavior was not mediated by participants' mood. It is also similar to that reported by Shariff and Norenzayan (2011, p. 807) who used an implicit visual priming.

However, there was a general effect of mood on WTC and WTP; a more positive mood was associated with higher WTC and WTP.

The reported congruency effect cannot be accounted by a symbolic association between the smelling of a "clean odor" and the activation of the concept of "cleanness" (both in physical and moral terms). Our results indicate that the influence of a clean odor on pro-social behavior depends on the interaction between odor and type of problem. For example, although the same clean scent (lemon) was dispersed in the room, people were affected by it (compared to the no-odor baseline condition) when they were evaluating a congruent problem (lemon tree reforestation; WTC: 83.3% and 50%, respectively), but not when they were evaluating an incongruent one (pine tree reforestation; WTC: 63.2% and 63.6%, respectively).

We suggest that the reported findings can be accounted by the notion of "accessibility" (Bone & Ellen, 1999) or the "ideo-motor" principle (Holland et al., 2005). More accessible information or concepts have the greatest influence on cognition and behavior. The priming of the stereotypical social category "elderly" makes people walking slowly (Bargh, Chen & Burrows, 1996). The mental accessibility of the concept of "cleaning" makes people think that they are more likely to plan cleaning-related action during the rest of the day (Holland et al., 2005) and the priming of the concept of "largeness" increases the estimates of physical quantities (Oppenheimer, LeBoeuf & Brewer, 2008). In the same way, the mental accessibility of the notion of "lemon trees" induces people to contribute more for a lemon-tree reforestation plan. The notion of accessibility might also account for Lilienquist et al. findings. It is not the symbolic value of the clean feature of an odor per se that affects behavior but rather the greater accessibility of the concept of "morality" that makes people more willing to support a public cause.

We are not arguing that the semantic relationship between the olfactory experience and the available concept is fixed or automatic. To the contrary, one quality of odors is their ambiguity. That is, their identification and interpretation is strongly context-based. For example, the ability to recognize a lemon scent is greater when the scent is presented in a yellow liquid as opposed to a red liquid (see the review of Bone & Ellen, 1999, p. 253). Thus, the same odor cue (e.g. a lemon scent) might make more or less available the notion of "lemon tree" as a function of other contextual cues. This might help to explain why we found no differences between the incongruent and control conditions. This could be due to the fact that the same lemon odor might only weakly activate the concept of "lemon tree" when people are focused on the evaluation of a pine tree problem.

It should also be noted that ambient odors seem to exert an influence on pro-social behavior via an unconscious path since people did not notice a specific scent in the room, nor did they recognize its influence on their decisions. This finding dovetails those reported by Holland, Hendriks and Aarts (2005), and Liljenquist, Zhong and Galinsky (2010).

As indicated in the Introduction, marketing practitioners already acknowledge that odors influence consumers' choices. Our study shows that odors, when they are semantically congruent with a public good, can influence the perception of the value of the public good and increase the willingness to financially support it.

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4.7 References

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CHAPTER 5

Paper II: Lexical and donation decisions under olfactory and visual stimuli

5.1 Abstract

Previous studies on the effect of ambient odors on decision-making processes indicate that semantically congruent odors enhance the perceived value of a public good (Bonini et al., 2012). In this study we investigate the underlying mental process: in the first experiment we used a lexical decision task in order to asses how odors affect the availability of related concepts/words. In addition, we included coherent visual stimuli, in order to study how different modality could affect the availability of concepts. The second experiment extends the findings of Bonini et al. 2012 to the evaluation of public goods, and show how pleasant and semantically congruent odors and pictures drive the evaluation of a public good.

Keywords: ambient scent; public goods; lexical decision; semantic congruity; accessibility; mood; cognitive processes.

5.2 Introduction

We are frequently exposed to several fragrances and we are not always aware of their effect on our behavior. When we read the literature on this topic we find numerous controversial explanations about the role of odors in our life. In particular, many studies found effects of ambient odors on different cognitive processes and domains.

In the linguistic domain, only few scholars studied the effect of odors. Holland et al. (2005) used a lexical decision task and reported a facilitation effect on words related to cleaning (faster responses) in presence of a fresh citrus odor, compared to control words. Hermans et al. (1998) showed how an emotional odor priming (positive or negative valence odors) improves the speed of target words recognition, when words and odors have the same valence (e.g., positive-positive).

On the contrary, in the decision-making domain there are several results about the effect of odors. A series of studies on retail behaviors supports the notion that a pleasant odor dispersed in the ambient increases the sales and enhances the perceived value of the goods (for a review see Turley & Milliman, 2000). Liljenquist et al., 2010 showed that an odor related to the concept of cleanness (a citrus-scented cleaning product) makes people more generous in different economic games. Moreover, odors can drive the participants to allocate money more generously when odors and domain are congruent (e.g., lemon odor and donations to a lemon garden), compared to

a non-congruent odor-good pair (Bonini et al., 2012).

Some studies highlight the role of mood in the perception of a positive odor and the resulting effect on the cognitive processes. However, it seems that mood alone couldn't be the sole explanation of many findings. In fact, pleasant odors aren't always responsible for a mood increase (Michael et al., 2003; Lombion et al, 2008) and several cognitive facilitation effects in the presence of an odor occurred without a mood elevation (Moss et al., 2008).

An alternative possible explanation for this effect could be the contextual association between concepts. According to Johnson (2011), odors may act as contextual cues that activate related memories. In particular, the author reports a possible semantic link between odors and decisions and this could explain the congruency effect found by Mitchell et al. (1995). In this study the authors reported that when a product was presented together with a congruent odor, the participants tried several different products (variety seeking decision strategies) than when the products and odors were not congruent. Johnsons (2011) reported also an additional mechanism involved in this sort of facilitation: the expectations, i.e. if we are exposed to an odor we have expectations about the odor source, which must be congruent.

The present study can be considered a novelty because it discusses the difference between two distinct cognitive mechanism: the linguistic elaboration of words and the decision making process under odor effect. We present two studies aimed to assess if pleasant odors or pleasant images impair or enhance our performance in a lexical decision task and modify the decision to donate money in favor of a public good. The goal of the study is to highlight differences and common points of these two different cognitive processes when a pleasant odor is present in the air.

5.3 Experiment 1: Lexical decision task

5.3.1 Method

Participants

A group of 144 students (64 males and 80 females, mean age = 22.9 years, SD = 4.8) took part in this experiment. They were naïve to the purpose of the study and reported a normal sense of smell, no history of olfactory dysfunction and no drug abuse. All the participants were not aware of the odor presence (in case of ambient odor exposure) and of the experimental aims and hypothesis of our study.

Design

The experiment has a between subject design with five experimental conditions: two conditions with an olfactory stimulus (lemon and pine odor), one condition with a visual stimulus (an attractive picture of a lemon) and a control condition (no experimental stimuli). Participants conducted a lexical decision task in a room (3 by 3 meters), the lemon/pine scent was diffused by putting 5 drops of essential oil in a candle diffuser with 15 cl of water. The candle diffuser was hidden and not visible to the participants. In the visual stimulus condition the lemon picture was presented on the screen of the computer during the lexical decision task, during the inter-stimulus-interval (ISI = 1000ms). In the control condition, no scent was diffused.

Stimuli and Procedure

Two pleasant odors (lemon and pine) were selected on the basis of a pilot study with twelve participants (six males and six females). Participants

entered in random order in 4 pre-aerated rooms in which we dispersed a constant quantity of ambient fragrance (pine, lemon, Calone or Ambre). We used essential oils for the pine and lemon odors. Calone and Ambre are fragrance solutions created by Firmenich and they have tones that resemble the sea breeze odor. After 30 seconds the participants started to rate the odor intensity, pleasantness, unpleasantness and familiarity (Labeled Magnitude Scale, LMS, Green et al., 1996) and then they described their memories related to each fragrance. The participants also reported how clean they perceived the experiment room. The results show that lemon and pine fragrances are similar on the intensity, familiarity, pleasantness and unpleasantness evaluation scales. The pine fragrance is semantically related to forest ecosystem, trees, mountain and relax sensations, whilst the lemon fragrance is related to lemon gardens, sweet things (e.g., cakes, candies and spirits) and pleasant memories about childhood. Participants didn't report memories about sea when they were exposed to Calone and Ambre, so we included in the experiment only the lemon and pine odors. A lemon image was selected with a pilot study ran on twenty participants, the image was considered the most pleasant and the most representative of the concept "lemon garden" in a set of ten images.

The stimuli of the lexical decision task were 78 real words and 78 non-words. Thirteen of the real words are related to the concepts "lemon" (e.g. lemon, orange, yellow) and "cleanness" (e.g. clean, fresh, pollution). Each of these thirteen words was matched with another real word that served as control. The lemon/cleanness words and the corresponding control words had the following characteristics: same number of syllables, similar number of letters (equal number or plus/minus one letter) and similar usage frequency (we calculated the natural logarithms of the usage frequency, lemon/cleanness words and control words have the same frequency, up to two decimal places).

The data on the usage frequency are based on itWaC, a large corpus of Italian words, built by web crawling (Baroni et al., 2009). In the lexical decision task, participants were asked to indicate as quickly and accurately as possible whether a letter string appearing on a computer screen was an existing word. For half of the participants the "n" key was associated to the answer "word" and the key "x" to "non-word", while for the other half of the participants the association was the reverse.

5.3.2 Results

For the analyses of the reaction time we used a Generalized Estimating Equations model (GEE; Hosmer & Lemeshow, 2000) that allows inclusion of categorical within-subject factors. The following factors were entered into the model: the experimental condition (a categorical, between-subject variable: lemon odor, pine odor, lemon picture and control), the type of word (a categorical, within-subjects variable: lemon related words and control words) and the reaction time (RT; a continuous variable). The model indicates a significant effect of the factor Condition (Wald$\chi^2(3) = 69.3$, $p < .001$) and, in particular, the average reaction times in the three conditions (see Figure 5.1) with facilitating stimuli are significantly faster than the control condition but not significantly different from one another (lemon odor = 674ms, SD = 24.1; pine odor = 656ms, SD = 25.8; lemon picture = 719.2, SD = 29; control = 1008.5, SD = 37, all the comparisons between the control and the other conditions are significant, $p < .001$). The factor Word Type is also significant (Wald$\chi^2(1) = 67.6$, $p < .001$ – the lemon-related words on average are recognized faster than the control words, 730.5ms vs. 798.5ms).

Finally, the most relevant result is the significant interaction Condition by Word Type (Wald$\chi^2(3) = 10.4$, $p = .015$). Lemon-related in the lemon

odor condition are recognized faster (633.9ms, SD = 19.8) than the same words in the lemon picture condition (702.7ms, SD = 30.1) – this difference is marginally significant (p = .056) – and they are recognized faster than the control words in the lemon odor condition (714.4ms, SD = 28.8, p < .001). However, the reaction time for the lemon-related words in the pine odor condition is similar to the reaction time in the lemon odor condition (623.7ms, SD = 24.9; p = .749). Similarly, the reaction time for the lemon-related words in the lemon picture condition is faster (702.7ms, SD = 30.1) than the reaction time for the control words in the lemon picture condition (735.7ms, SD = 29.0; p = .004), the RT for the lemon-related words in the control condition (961.6ms, SD = 36.9; p < .001) and the RT for the control words in the control condition (1055.4ms, SD = 42.0; p < .001). Overall, the results indicate that a semantically congruent priming stimulus has a facilitation effect on the word recognition task and this effect is stronger for an olfactory stimulus, compared to a visual one. However, a pleasant and unrelated odor (pine) has the same facilitation effect of a pleasant congruent odor.

5.4 Experiment 2: Public good evaluation

5.4.1 Method

Participants

A group of 158 foreign students from the University of Trento Italy (85 males and 73 females, mean age = 25.1 years, SD = 4.1) took part in this experiment. They were naïve to the purpose of the study and reported a normal sense of smell, no history of olfactory dysfunction and no drug abuse.

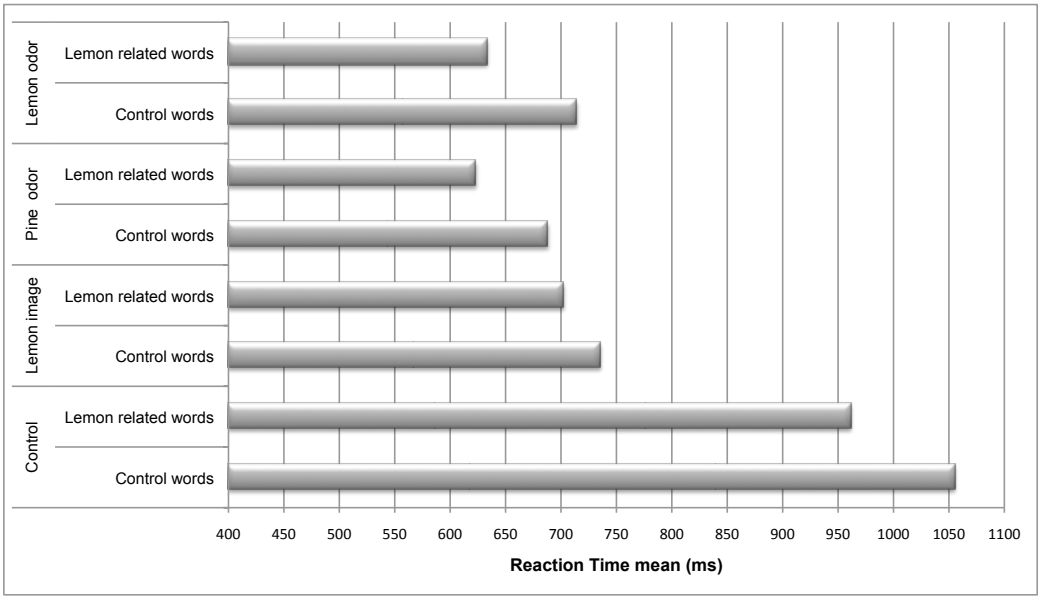

Figure 5.1: Mean Reaction Times by stimulus condition and word type.

All the participants were not aware of the odor presence (in case of ambient odor exposure) and of the experimental aims and hypothesis of our study.

Design

A Scenario (Garda lemon-gardens replanting) was presented with five stimuli conditions (lemon odor, lemon image, pine odor, pine image and control condition) in a between subjects design.

Stimuli and Procedure

We used the same stimuli presented in experiment 1: lemon and pine odors, lemon picture and we added a new stimulus, a pine picture. The pine picture is as attractive as the lemon picture and it is the most representative of the concept "pine wood" in a set of ten images. Each participant was randomly assigned to one of five conditions: odor congruent with the

decision task (lemon odor and lemon garden problem), odor not congruent with the decision task (pine tree odor and lemon garden problem); image congruent with the decision task (lemon gardens image and lemon garden problem); image not congruent with the decision task (pine tree image and lemon garden problem); control condition (lemon garden problem, with no odor and no image). In the olfactory stimulus conditions a fragrance (pine or lemon, depending on the experimental condition) was dispersed in a pre-aerated room, using the same methodology presented in experiment 1; the quantity of the fragrance was held constant between conditions. In the visual stimulus condition an A3 sized image showing a lemon garden/pine tree was displayed on the wall in front of the participants. No specific stimulus was presented in the control condition. Soon after entering the room, participants filled an ostensibly unrelated questionnaire (it was presented as a questionnaire for an unrelated undergraduate research) where they rated their current mood by completing seven semantic differential scales, each ranging from -3 to +3. Each scale was constructed on bipolar adjective pairs (e.g., tense-relaxed; disappointed-satisfied), and was adapted from Ehrlichman and Bastone (1992). We counterbalanced the affect labels (e.g., tense-relaxed; relaxed-tense) to avoid any order effect. Then, we presented the scenario and the decision task. The scenario referred to an environmental hazard (e.g. a parasite attack) and a public action aiming to fix it (e.g. a replanting plan). The scenario was the same for all the stimuli conditions. Participants were first asked whether they were willing to contribute (WTC) for the public action (e.g. lemon-tree replantation), and, in case of an affirmative response, how much they were willing to pay (WTP). The suggested contribution was 10 euro (that was a useful anchor to address the WTP amounts). After the decision task the participants answered a few questions

about the previous experiences with the public good (Garda lemon gardens). Finally, there were three questions about the perception of cleanness in the experimental room and we also asked the participants if they perceived any particular odor.

5.4.2 Results

The percentages of participants willing to give a contribution to the proposed action were (Wald$\chi^2(4) = 10.7$; p = .030): 83% (lemon odor), 63% (lemon picture), 63% (pine odor), 50% (pine picture) and 50% (control). Subsequent tests contrasting pairs of conditions evidenced a significant difference between lemon odor and control: 83% vs. 50%; Wald$\chi^2(1) = 8.12$; p = .004. The difference between the control condition and the remain conditions are not significant. Table 5.1 reports WTC (%) and WTP/Donations[1] (SD) for the two public goods.

Garda lemon gardens evaluation						
WTC	Stimulus Type					Total
	Control	Lemon odor	Pine odor	Lemon image	Pine image	
Yes	19 (50%)	25 (83.3%)	19 (63.3%)	19 (63.3%)	15 (50%)	97 (61.4%)
No	19 (50%)	5 (16.7%)	11 (36.7%)	11 (36.7%)	15 (50%)	61 (38.6%)
Total	38 (100%)	30 (100%)	30 (100%)	30 (100%)	30 (100%)	158 (100%)
Mean WTP (SD)	6.97 (10.50)	15.60 (15.44)	7.23 (10.10)	11.13 (13.62)	10.10 (16.96)	10.04 (13.64)

Table 5.1: WTC (%) and mean WTP (SD) by stimulus type.

Participants who attributed a greater importance to the public good protection are more willing to contribute: β= 0.78; Wald$\chi^2(1) = 24.6$; p < .001. The mean euro amounts that the participants were willing to pay for the proposed action were: €15.6 (lemon odor), €11.13 (lemon picture), €7.23

[1]The term "Donations" indicates that people actually donated some money for the public goods.

(pine odor), €10.10 (pine picture) and €6.97 (control). An ANCOVA analysis on WTP evaluations (winsorized at €50), using perceiving importance as covariate, showed a non-significant effect of the stimulus type: $F(4, 152) = 2.025$; $p = .094$. The covariate factor "perceived importance" had a significant impact on WTP: $F(1, 152) = 31.35$; $p < .001$.

5.5 Discussion

The results show a clear difference between the cognitive processes associated to the lexical decision and choice tasks. Both odors and pictures have a facilitation effect on the ability to correctly recognize words (compared to non-words), but pleasant odors have a particularly strong effect. Whilst, congruent and incongruent odors have similar effects in the lexical decision task – it seems that their ability to facilitate word recognition is not due to the semantic relationship but to theirs hedonic value. This result extends previous findings (Holland et al., 2005), which were limited to a single congruent odor.

On the contrary, in the decision task the congruency factor plays a crucial role: the lemon odor (a pleasant and congruent stimulus) increases significantly the intention to financially support an environmental public good. The pine odors and the two pleasant pictures have only a limited effect on the WTC and WTP. Interestingly, we found a difference between two congruent and pleasant stimuli: the lemon odor and the lemon picture. In both tasks these stimuli affect the performance (lexical decision) or the choice, but the olfactory stimulus has a stronger effect, compared to the visual stimulus. This result seems to indicate a cognitive preferential channel of odors.

Previous results indicate how odors quickly reach the emotional system.

In particular, olfactory afferent mechanisms have a direct connection with the "amygdala-hyppocampal complex": the neural substrates for the emotional processing (Turner et al., 1980; Cahill et al., 1995). Interestingly, these synaptic links make possible not only the emotional processing of the odors, but also their emotional memory maintenance. This direct relation between odors, emotions and memory, compared to other sensory modality, provide an evidence for a more direct influence of odors on cognitive System 1, responsible for immediate and emotionally based decisions. It seems that the olfactory stimuli drive our decisions and, in some cases, follow their scent might be for the better.

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CHAPTER 6

Paper III - Low concentrated ambient delivered 4,16-androstadien-3-one, Dictator and Trust games

6.1 Abstract

However, whether chemosignals can exert an impact on economical decision-making is poorly understood, we report the results from a repeated Dictator and Trust Game study. Dictators were asked to choose how much to offer (any amount from 0 to 8 dollars) to a Recipient showed in a picture. Then they played a repeated Trust Game in the role of the Trustor. The participants took their decisions in a room where androstadienone (AND) in solution with clove oil was released, and in a room with only clove odor. The donations were higher in the AND condition. Male and female participants also reported an increase of positive mood in presence of AND. We explain our results in terms of a mood effect: people in a good mood prefer to confirm

this emotional state, without taking any decision that could compromise it, shifting them in a worst mood. Moreover AND had an effect on Trust Game with higher demonstration of trust.

Keywords: androstadienone, olfaction, mood, Dictator Game, Trust Game, generosity

6.2 Introduction

"No person was ever honored for what he received. Honor has been the reward for what he gave."

Calvin Coolidge, reported in Thompson, 1924, p. 47.

Several studies in the last thirty years have shown a strong relationship between positive affect and prosocial behaviors. It seems that a positive mood could mediate a lot of behaviors, making people more generous, more helpful to the others and more interpersonal understanding (e.g., Aderman, 1972; Cunningham, 1979; Cunningham et al., 1980; Isen, 1970; Isen & Levin, 1972). For example, in a famous series of studies conducted from the Seventies the participants who were unexpectedly offered a cookie donated more to good causes, were more glad to help someone in carrying several heavy books and were more willing to help a passerby who dropped a folder of papers, and so forth (see, Isen, 1970; Isen & Levin 1972; Isen, 1987; Isen 2001; Isen, 2008).

In many studies the experimenters induced an incidental positive affect in the participants, by giving a little gift or something to eat (a cookie or candies) to the participants, or by showing happy faces or comical movies. Mellers et al. (2010) reported that participants who were in a condition of induced positive mood (by giving a candy bag or seeing a comedy routine)

shown more fairness in an economic game such as a Dictator game. They explain this change in the Dictators self-interest with a sort of mediation caused by the induction of an incidental positive mood. In particular, the authors assess that a positive mood creates a shift in the prosocial behavior and consequently the participants consider other people's happiness more enjoyable.

Pleasant odors could also trigger a positive affect state. Many studies reported that a fragrance could elicit a positive mood that has a consequential action on the individuals' choices (for a review on this topic see Turley & Milliman, 2000). In particular, a pleasant odor increases the mood in persons exposed to it, modifying the choice strategies involved in a decision making process and changing the final choice. Detectable and pleasure odors are not the only kind of odors which could cause these changes, but also the so-called chemosignals, when inhaled, can improve the mood. The most used compound in this research field is androstadienone (4,16-androstadien-3-one; AND), a volatile molecule derived from testosterone and present in higher concentration in males, compared to female (Brooksbank et al., 1972). The AND's occurrence was tested in human body fluids such as sweat (Labows, 1988) and semen, plasma (Nixon et al., 1988; Rennie et al., 1990; Kwan et al., 1992), ovaries and adrenal glands in women and men (Smals & Weusten, 1991; McClintock, 2000). Androstadienone is considered the most prevalent steroid on the skin surface and axillary hair follicles (Preti & Wysocki, 1999).

These findings make the AND the best candidate to be regarded as a putative human chemosignal. Moreover the first definition introduced by Karlson and Luscher (1959) assesses that chemosignals are not only substances present on the body, but also they are *"substances [...] perceived by a second individual of the same species in which a specific response is*

induced, for example a specific form of behavior or process of development". Furthermore, there are a lot of psychophisiological evidences that agree on considering AND as a human chemosignal. Some studies showed that the mood state of women exposed to AND improves (Jacob & McClintock, 2000; Jacob et al., 2002; Lundström & Olsson, 2005), while men's mood has a negative trend or, at best, it remains at the level previously reported (Jacob & McClintock, 2000; Bensafi et al., 2004b; Villemure & Bushnell, 2007). Heterosexual women also shown an increase in mood and in arousal, but only if the experimenter is of the opposite sex (experimenter gender effect; Lundström & Olsson, 2005) and he is present throughout the study (Hummer & McClintock, 2009). Moreover, Grosser et al. (2000) showed that AND injected directly into the VNO (Vomeronasal organ, which is involved in the chemosignal elaboration in animals), causes in women a significant reduction in emotional states with negative connotations like nervousness, boredom and frustration, and it leads to accelerated physiological levels of preovulatory hormone production (luteinizing hormone, LH), a decrease of respiratory frequency and heart rate, a reduction in the psychogalvanic response and an increase in the alpha cortical activity and in body temperature. These psychophysiological changes (with the hypothalamus mediation) may have the function to prepare the woman to sexual intercourse, as happens in animals. Women expose to AND also shown activation in brain areas associated with attention, social cognition, emotional processes and sexual behavior (Gulyas et al., 2004, Jacob et al. 2001b; Savic et al., 2001, Savic et al., 2005).

The aim of this study is to investigate the possible implications of androstadienone inhalation on complex cognitive process, such as economic decision-making. In particular, we desire to investigate if and how the exposure to androstadienone would affect the decision to adopt fair or unfair

behaviors (e.g., donation of money during an economic game).

The general hypothesis underlying this study is that AND has a modulation effect on decision-making processes involved in economic games. We suppose that this putative human chemosignal could operate as a chemosignal, activating instinctive and emotional factors that change the evaluation of information available to individuals, in our case information on social norms, such as generosity and trust.

6.3 Methods

6.3.1 Participants

Twenty-nine participants (19 women, mean age = 28.37 and 10 men, mean age = 25.60; age range: 20-40 years) took part in this experiment. They were all Northwestern University of Chicago employees and students with mixed ethnic backgrounds. All of the participants were naïve to the purpose of the study and completed an informal questionnaire beforehand to ensure that they had no history of neurological or psychiatric disease, no history of smell or taste problems, no use of medication including contraceptives, and no drug or tobacco abuse. All the participants provided informed consent approved by the Northwestern University Institutional Review Board and were paid upon completion of the experiment.

6.3.2 Compounds

AND was obtained from Steraloids Inc. (Newport, RI, USA) and prepared in solution following prior methods (e.g., Filsinger et al., 1985; Jacob & McClintock, 2000; Lundström et al., 2003; Lundström & Olsson, 2005;

Hummer & McClintock, 2009). For the experimental session we dissolved 5 mg of AND into 72 ml of clove oil (Sigma-Aldrich, USA) as cover odor, resulting in an AND concentration of 250μM. This approach was taken to ensure that the AND was not consciously detectable in the presence of the clove fragrance. Clove oil alone was used as the control stimulus. Depending on the experimental session, 5 ml of either the AND/clove solution mixture or the clove control solution were put into 3 identical 20-ml uncapped opaque jars (4.3 cm in diameter at the opening; 7.5 cm high). To obtain an ambient odor stimulation we positioned the jars near the participants but hidden from their view, to prevent participants from gaining overt awareness about the purpose of the study.

6.4 Procedure

6.4.1 Discrimination screening

On the first day we verified the participants' performance using a three-way forced-choice olfactory discrimination task ("triangle" test). Subjects were presented with three bottles: one bottle containing the mixture (AND with clove oil) and two bottles containing only clove oil. The task was to select which bottle contained a different smell, after sniffing the three bottles seven times each. The screening was performed six times in order to exclude from the sample anyone who could reliably detect the presence of AND, and to be sure that the two solutions were perceived as the same odor. We discarded any participant who correctly identified the AND bottle on more than 4/6 trials. We excluded 3 participants.

6.4.2 Main study

In the main study, participants played the Dictator game and the Trust Game on two separate days, once in the presence of AND/clove and once in the presence of clove only (see Figure 6.1). A female investigator was present at every stage to prevent the experimenter effect (Hummer & McClintock, 2009). On each day, participants first completed a pencil-and-paper mood questionnaire, which was conducted in a non-scented room. These initial ratings signified "initial mood". Participants reported how strongly they were experiencing each of 16 different affective states on a 9-point scale, with 1 corresponding to "not at all" and 9 corresponding to "very strongly". The questionnaire was adapted from Ekman et al., (1980) and Levenson et al. (1990). This inventory is validated and it consists of the following affective states: afraid, amused, angry, annoyed, anxious, bored, calm, confident, content, contemptuous, disgusted, embarrassed, happy, interested, sad, and stressed. Participants were then brought into the scented room (containing either AND/clove or clove only, depending by the condition), where they repeated the same mood questionnaire on a PC computer running ePrime 1.0 software (Psychology Software Tools, Inc.; http://www.pstnet.com; Schneider, Eschman, & Zuccolotto, 2002a,b), in order to assess the effects of the initial odor stimulation on mood. We call this mood rating "first mood". After this task two economical games were presented on the computer.

The Dictator Game (Kahneman, Knetsch & Thaler, 1986) is a classical game that provides a behavioral index of the participants' altruism. It begins with the "Dictator" being in possession of a certain amount of money (in this case $8 for each trial). The Dictator then makes a donation to the "Recipient" (allocation). Only the Dictator can determine the size of the shares, and the Recipient can only accept the proposed division.

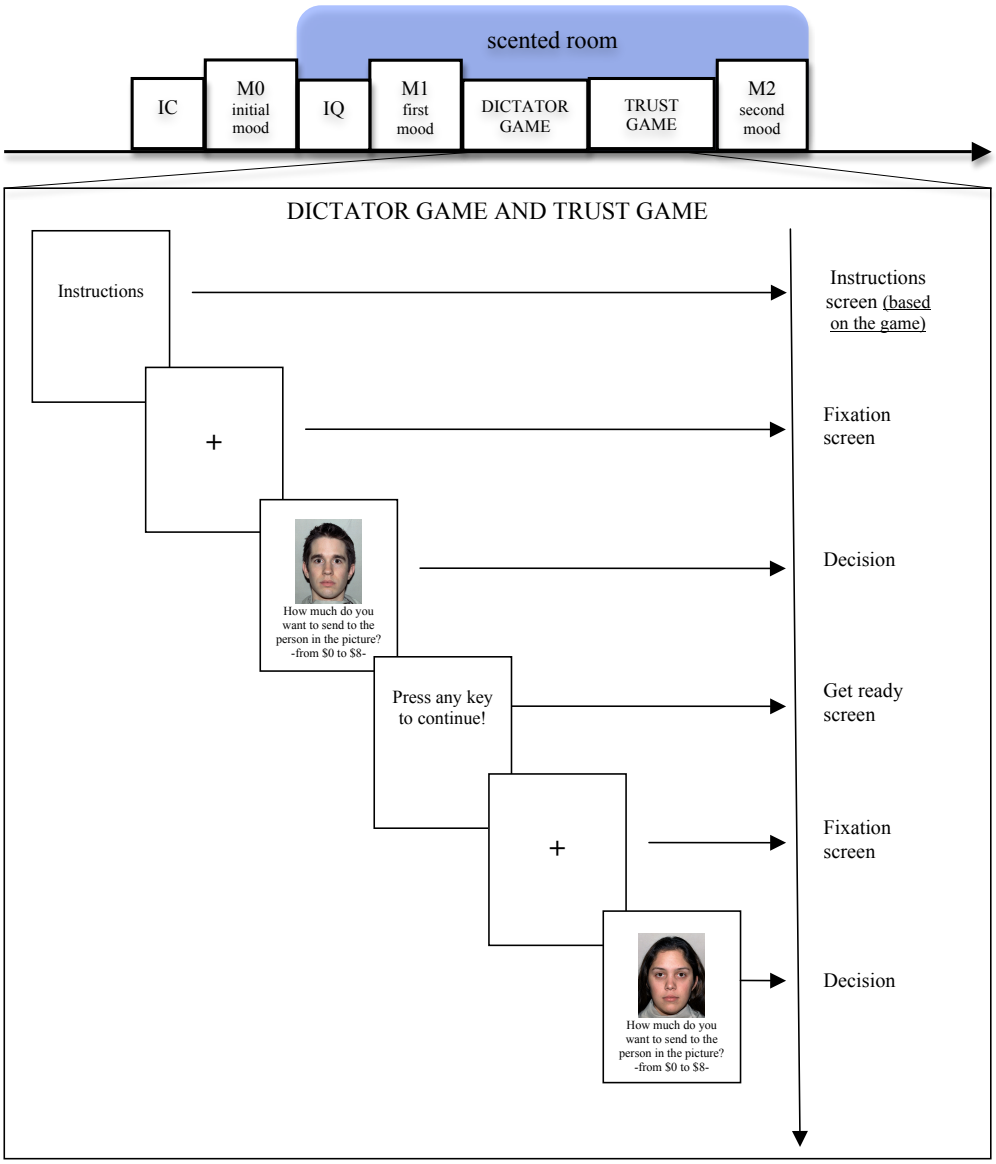

Figure 6.1: Schematic depicting experimental paradigm (upper panel) and typical trial sequence during the games (lower panel). Each participant was tested with both odors (androstadienone in clove oil, clove oil alone). Key: IC, informed consent; IQ, information questionnaires.

The Recipients were presented with pictures taken from the NimStim set of facial expressions (Tottenham et al., 2009). A total of 42 different faces, limited to those with a neutral facial expression, were used. Participants played 42 trials of the Dictator Game as the Dictator, once in the AND in Clove oil condition, once in the Clove oil only condition. Before the beginning of the game the participants red the instructions and were given the opportunity to ask questions. They were also informed that they would be paid, according to their performance in the game, as a motivational incentive to perform well (payment range: from 20 to 30 dollars). Specifically, $20 was the show-up fee and the rest of payment was based on one of the 84 trials, selected at random.

At the beginning of the game, and on each trial, a photograph of a Recipient was presented on a computer monitor to the Dictator, who decided how much money (from zero to $8, in one-dollar increments) give to the Recipient. Participants had unlimited time to make their decision, and after the decision the Recipient photograph disappeared. No other information about the Recipient was given.

The second game was the Trust Game. The game begins with the "Trustor" (player 1) being in possession of a certain amount of money ($8 for each trial). The Trustor then passes a certain amount to the Trustee (player 2 showed in a picture) as a trust demonstration. The amount of money passed to the Trustee is then multiplied three times by the experimenter. The Trustee is then able to pass money back to the Trustor to reciprocate the trust.

Participants played 42 single-shot trials of the Trust Game as the Trustor and they were deceived into believing that their co-players had agreed to come to the lab within 2 weeks to respond to their offers. As a consequence, this version of the Trust Game can be considered an extension of the Dictator

Game, where the player 1 has an additional motive to donate money: the hope that player 2 will reciprocate. A single round of the Trust Game began with a 2 second fixation point (see Figure 7.1). Following this, the co-player's photograph (NimStim set of facial expressions; Tottenham et al., 2009) was presented for the time to decide how much of $8 to invest in their co-player. Participants had unlimited time in which to make their decision. No other information about the co-player was given. These screens were presented in both games. On the same screen, participants submit their offer pressing the number decided on the keyboard.

The Dictator Game trials were structurally identical to the Trust Game trials, with only slight word changes to reflect the differences in the games. The participants played 42 single-shot trials of the Dictator Game as the Dictator. During the experiment, participants played each game in block format, completing all 42 trials of one game, and then completing all 42 trials of the other game.

All participants were tested in both experimental odor conditions on different days, following recently published methods (Hummer & McClintock, 2009). The sequence of odor conditions was temporally counterbalanced across participants. The same tasks were presented to the participants in both odor conditions.

The 42 Recipients' photographs were presented in the two blocks in fully randomized way, such that the participants saw the pictures in different orders, to prevent any possible practice effect.

Following the completion of the task, in both odor conditions participants were debriefed on all deception used in the experiment.

Note that the interval between the odor presentation and the end of the decision-making task was from the 5th to 20th minute from the entrance

in the scented room in all conditions. This rationale was based on the observation that the effects of AND on physiology and behavior appear to be time-dependent, diminishing after the first 20-30 minutes after exposure (e.g., Saxton et al., 2008; Grosser et al., 2000). In particular Grosser et al. (2000) reported that the AND presence shall not have any psychophysiological effect after a point in time assessed between the 15th and the 35th minutes after the first exposure. However Jacob and McClintock (2000) pointed out slight psychophysiological modifications up to two hours from the first exposure.

At the end of the experiment, participants were asked to rate their mood ("second mood") one more time with the same method described above, to assess any further impact of odor or of the tasks.

6.5 Results

6.5.1 Mood

We first analyzed the effects of AND exposure on mood, given the reported effects of this compound on a variety of emotion- and mood-based behaviors. As in Bensafi et al. (2004b), the 16 Ekman's mood scales were reduced into three main clusters: "positive mood" (calm, content, confident, happy, interested, and amused), "high arousal negative mood" (contemptuous, embarrassed, afraid, disgusted, angry, anxious, and stressed), and "low arousal negative mood" (sad, annoyed, and bored).

Figure 6.2 shows the mean in positive mood on the different odor conditions divided by time of measure (e.g., initial, first and second mood).

A repeated measures 3x2 ANOVA was carried out with the following independent variables: odor (2 levels: AND with clove oil, and clove oil alone) and time (3 levels: 3 mood measures during the experiment), positive mood

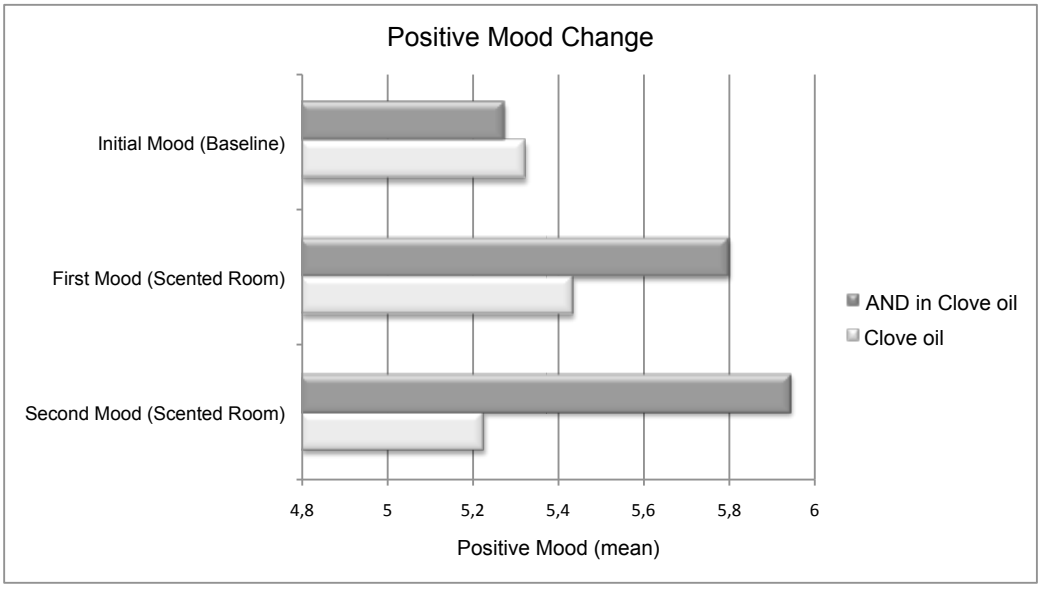

Figure 6.2: Change in positive mood level across the three mood ratings, differentiated by odor stimulus type. AND, androstadienone.

as dependent variable and the participants' gender as a between subject factor. The analyses shows a significant odor effect (F (1,27)=4,324; p=0.047) and a significant odor by time interaction (F (2,26)=3,115; p=0.034) on positive mood. The data show no significant odor by gender effect on positive mood (F (1,26)=1,181; p=0.287). No significant effects were observed for the remaining mood categories ($p > 0.05$ in all cases). The positive mood increased following the odor exposure, but more with AND than with only clove oil. The "positive mood" increased both in women and in men.

6.5.2 Mood and Dictator choices

The AND stimulation increases the DG donations (Mean=$3.27; SD=1.92), compared to the clove oil control condition (Mean=$3.05; SD=1.73). To gain a more systematic understanding of the factors that influenced the donation

amount, we used the Generalized Estimating Equations model (GEE; Hosmer & Lemeshow, 2000) that allows inclusion of categorical within-subject factors. The following factors were entered into the model: AND stimulation (a categorical, within-subjects variable), gender (a categorical, between-subject variable), Δpositive mood and Δlow-arousal negative mood (from initial to first, two continuous variables), and the amount of the donation (a continuous variable). Mood was expressed in terms of difference between the initial mood value and the first mood, in order to measure the mood change generated by the odor stimulation. The mood clusters unaffected by the chemosignal manipulation were not included in the analysis. We tested different GEE models, and compared them using a Goodness-of-Fit statistic, the Quasi-Likelihood Under Independence Model Criterion (QIC). The model with the best Goodness-of-Fit statistic (QIC=153.96) showed a significant effect of "AND stimulation" (Wald$\chi^2(1) = 22.48$, $p < .001$), a significant effect of "Δpositive mood" (Wald$\chi^2(1) = 6.85$, $p = .009$) and a statistically significant interaction: "AND stimulation by Δpositive mood" (Wald$\chi^2(1) = 11.71$, $p = .001$). These findings indicate that AND stimulation and positive mood both affect the donation amount.

6.5.3 Mood and Trustor choices

The AND stimulation increases the TG donations (Mean=$3.95; SD=1.56) compared to the clove oil control condition (Mean=$3.57; SD=1.53).

We run a GEE model with the following factors: AND stimulation (a categorical, within-subjects variable), gender (a categorical, between-subject variable), Δpositive mood and Δlow-arousal negative mood (from initial to first, two continuous variables), and the amount of the donation (a continuous variable). We tested different GEE models, and compared them

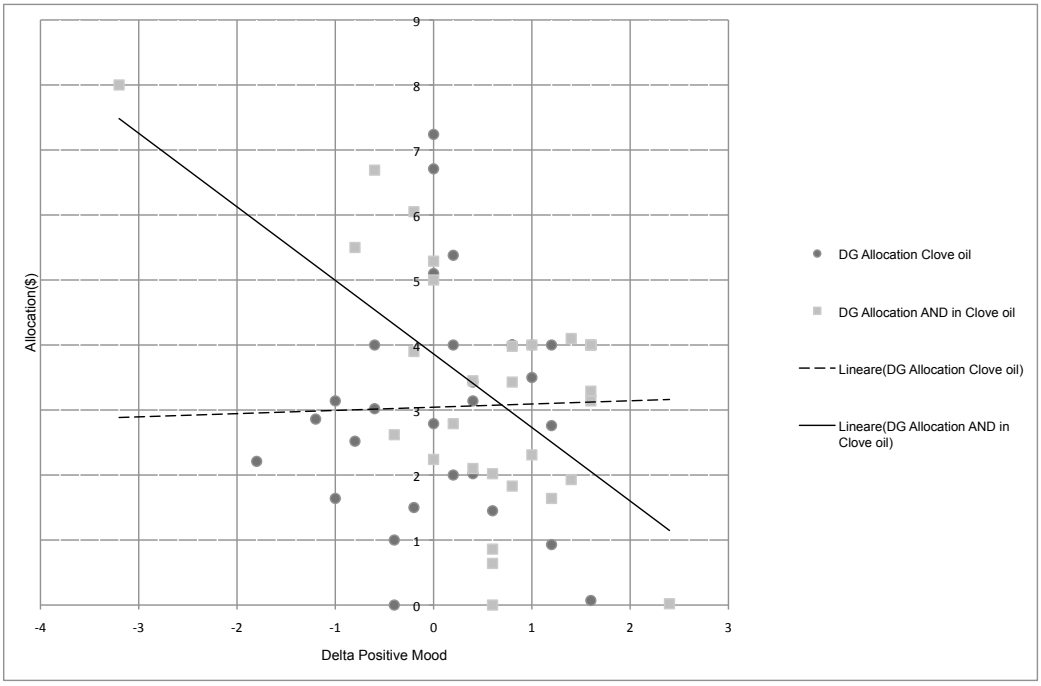

Figure 6.3: Interaction between putative chemosignal manipulation and Δpositive mood on Dictator Game allocations (the continuous regression line refers to the AND condition, the dashed regression line refers to the clove oil condition). Diamonds, AND+clove oil condition; squares, clove oil only condition.

using a Goodness-of-Fit statistic, the Quasi-Likelihood Under Independence Model Criterion (QIC). The model with the best Goodness-of-Fit statistic (QIC=125.78) showed a significant effect of "AND stimulation" (Wald$\chi^2(1)$ = 8.90, p = .003), a significant effect of "Δpositive mood" (Wald$\chi^2(1)$ = 4.92, p = .027). The interaction "AND stimulation by Δpositive mood" was not statistically significant. These findings indicate that AND stimulation and positive mood both affect independently the donation amount.

See Table 6.1 for a comparison between TG and DG results in term of mean in donations.

	AND in clove oil	clove oil
DG mean (SD)	\$3.27 (1.92)	\$3.05 (1.73)
TG mean (SD)	\$3.95 (1.56)	\$3.57 (1.53)

Table 6.1: Mean of game choices in US dollars divided by odor condition.

6.6 Discussion

We investigated the effects of androstadienone exposure on mood and on the performance in two economic games, the Dictator Game, that measures generosity/fairness and the Trust Game, that measures trust (Table 6.1 shows the main results). The studies reported in the literature have mainly investigated the effect of androstadienone perception on sexual behavior and emotional states. The interest for its action on complex cognitive processes is only limited to those fields. In the literature there are only a few studies that involve high cognitive processes. Lundström et al. (2003) show a greater

increase of selective attention (compared to distributed attention) in women when exposed to androstadienone. A more recent study (Hummer & McClintock, 2009) showed that androstadienone drives attention and perception to emotional and social information like affective faces with a greater intensity (compared to neutral expression faces or shapes). The novelty is that this is one of the first studies on the relationship between putative chemosignals and high cognitive processing, such as economic decision-making. The surprising result is that both men and women increased their positive mood. Many studies on mood reported no changes or a more negative mood for men exposed to androstadienone (Jacob & McClintock, 2000; Bensafi et al., 2004b). We found an increase in fairness in both men and women, with higher amounts given when the putative human chemosignal was present. Our findings represent a novel demonstration of the modulation of complex processes, such as decision making, by androstadienone. In particular, we could assess that this sex steroid expands generosity and trust levels, with a strong effect on the amount of money donate in a Dictator Game and in a Trust Game.

These results show that positive mood could increase the generosity, involving some selective strategies that promote an easier access to mood-consistent information in memory (Bower, 1981; Forgas & Bower, 1987), resulting in no changes in the emotional state. People that are generous in the Dictator Game, remain happy because they did something good for the others. This generosity could be explained with the Mood Manteniance Hypothesis (MMH; Isen & Labroo, 2003; Isen & Patrick, 1983). This approach suggests that people in a good mood prefer to confirm this emotional state, without taking any decision that could compromise it, shifting them in a worst mood. The Trust Game results seem to be an extension of this pro-

cess: persons in a good mood tend to trust more other people. It seems that this process is driven by the desire to obtain more at the end of the game. As aforementioned the Trust Game is a game in which the first player (Trustor) gives an amount of money to the second player (Trustee) that can reciprocate this "trust" by giving back an amount of money. In this case, it seems that the participants (always in the first player role) tried to be trustful only for self interest. As reported by Castelfranchi and Falcone (2010) *"the act of trusting is not a cooperative act per se. On the contrary, in a certain sense, the trustor is expecting from the other some sort of "help" (intentional or non-intentional): an action useful for the trustor."(p. 255).*

Many studies, in contexts different from the economic one, corroborate our idea that pleasant odors and chemosignals modify the decision processes. Li et al. (2007) showed an effect of below-threshold odors on likeability judgments of faces. In particular, they found that only the odor below the detection threshold could change social preferences in a likability rating on human faces. In a more ecological setting, Saxton et al. (2008) found significant effect of subliminal androstadienone perception in a social context such as a speed dating. In their study the participants were exposed to androstadienone in clove oil (or clove oil alone) and had to rate the attractiveness of some potential partners. The results showed that women exposed to androstadienone considered men more attractive than when exposed to the carrier. Furthermore, in a recent study on hormones and economical decision making Zak et al. (2007) reported that oxytocine modulates human decision making increasing the donations in Dictator Game and in Ultimatum Game (a game similar to Dictator Game where the Recipient can decide if accept or not the amount received). These results were consistent with a Harbaugh and collegues' (2007) fMRI study that found some neural evi-

dences in favor of two kind of selective activations, as a reason for charity. Their data showed how charity elicits neural activity in the ventral striatum areas which are linked to reward processing, that are activated when the person makes transfers voluntarily. In conclusion, we know that odor could modulate several processes such as affective states and attention. This study could open a new multidisciplinary approach that combines putative human chemosignals like androstadienone, odors and high cognitive processes such as decision making. It seems that not only pleasant odors, but also the so-called "human chemosignals" could drive our choices in real life context make us more generous with the others (but maybe also with us).

6.7 Acknowledgments

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CHAPTER 7

Paper IV - 4,16-androstadien-3-one makes women happier and more generous

7.1 Abstract

Putative human chemosignals have been shown to influence mood states and emotional processing, but their effect on higher-order cognitive processing is not well established. This study utilized an economic game (Dictator Game) to test whether androstadienone (AND), an odorous compound derived from testosterone and enriched in men, impacts on altruistic behavior. We found that women donated larger sums of money to recipients in the presence of AND, compared to a control odor (where AND was absent). Notably, this donation effect was most evident in women whose positive mood was also enhanced following exposure to AND. No such effects were observed in male participants. Our findings suggest that when accompanied by a positive

mood, AND has a more potent influence on altruistic behavior, as if mood state allowed "gating" of the chemosensory effect. This research highlights the capacity of human putative chemosignals to influence higher cognitive processes, in a gender-specific way.

Keywords: androstadienone, olfaction, mood, Dictator Game, generosity

7.2 Introduction

"Odors have a power of persuasion stronger than that of words, appearances, emotions, or will. The persuasive power of an odor cannot be fended off, it enters into us like breath into our lungs, it fills us up, imbues us totally. There is no remedy for it."

Süskind, 1985/2001, p.82.

The assumption that human beings act in their own self interest has been a dominant model of studies on economical decision-making. However altruistic behavior is a central element of modern societies (see Oppenheimer and Olivola, 2010, for a recent review on experimental studies on charity) that challenges these assumptions. Indeed, generosity is part of human nature, and in this study we show that it can be enhanced by chemical signals.

As Süskind implies, odors may have a stronger influence than other incidental information (i.e., not related with the problem at hand) in guiding our everyday behavior, perhaps reflecting the intimate anatomical overlap between the olfactory system and limbic brain networks regulating emotionally based responses (Gottfried, 2010). In the context of pro-social decisions Liljenquiest et al. (2010) showed that a pleasant odor affects the propensity to donate money for charities. Interestingly, not only detectable and pleasant

odors – but also putative olfactory chemosignals – are capable of eliciting behavioral changes. For example, Saxton et al. (2008) showed that the presence of a putative chemosignal (androstadienone) increases the perceived attractiveness of the male partners during a speed dating. Androstadienone (AND; 4,16-androstadien-3-one), a molecule derived from testosterone and present mainly in males, and present in higher concentration in males, compared to female (Brooksbank et al., 1972) is the compound most commonly used in experimental studies .

AND has been identified in human sweat, semen, and plasma (Labows, 1988; Nixon et al., 1988, Rennie et al., 1990, Kwan et al., 1992), ovaries and adrenal glands (Smals & Weusten, 1991; McClintock, 2000), and on the skin and axillary hair (Preti & Wysocki, 1999). Together these data suggest that AND might possess chemosignaling properties. Several studies indicate that AND improves positive mood (Jacob & McClintock, 2000; Bensafi et al., 2004; Lundström & Olsson, 2005) and activates brain areas associated with attention, emotional processes, and sexual behavior (Gulyas et al., 2004, Jacob et al. 2001; Savic et al., 2001).

In line with the concept of a sex chemosignal, many of the effects of AND seem to be gender-specific, such that this compound has a particular effect on emotional states (e.g., mood and attractiveness ratings) in females. The current investigation shifts the behavioral focus of AND from its well-known influence on emotional states to the cognitive processes involved in a rational choice. Specifically, the aim of our study was to investigate the role of AND in the context of an economic game. The Dictator Game (DG; Kahneman et al., 1986) is a classical game that provides a method of measuring altruism. In the DG, the first player, "the dictator", determines an allocation (split) of a monetary endowment. The second player, "the receiver", must accept

the proposal. This game was used to test the homo economicus model of individual behavior: namely, if individuals were only concerned with their own economic well-being, then the dictator would always allocate the entire good to themselves. Experimental results reproducibly indicate that individuals often allocate a portion of the money to the responders, reducing the amount of money they receive. Prior work on the DG has not reported systematic evidence for gender differences in the amount of donations (Croson & Buchan, 1999; Camerer, 2003). Here we hypothesized that AND unconsciously modulates altruistic behavior in this decision-making task, over and above the effects of AND on mood per se. Given that AND is prominent in men, we also predicted that the effects would be restricted to female participants.

7.3 Methods

7.3.1 Participants

Thirty-seven university students (19 women), with a mean age of 24 years (range 18-40 years), took part in this experiment. All of the participants were naïve to the purpose of the study and they all completed an informational questionnaire in order to verify that they had a normal sense of smell, no history of olfactory dysfunction, and no drug use including contraceptives. We also controlled for variations in menstrual cycle from influencing results by limiting testing in the female participants to the ovulatory period (12th-18th day post-menstruation). Before the beginning of the game the participants red the instructions and were given the opportunity to ask questions. They were also informed that they would be paid, according to their performance in the game, as a motivational incentive to perform well (payment range: from 8 to 24 euro). Specifically, €8 was the show-up fee and the rest of pay-

ment was based on one of the 24 trials, selected at random. The experiment was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

7.3.2 Compounds

AND was obtained from Steraloids Inc. (Newport, RI, USA). For the experimental condition we dissolved 5mg of AND into 3ml of Limonene (R(+)97%; Sigma-Aldrich, USA); the AND concentration was 650μM. We used this concentration, following Bensafi et al., 2004, because this dosage has an effect on the positive mood increase mainly in females. Limonene is a terpene with a light lemon-citrus odor and flavor commonly used in alimentary and cosmetic products. This odorant served as both carrier (containing AND) and as a control odor (presented without AND). AND was undetectable in this solution. We use Limonene as a carrier because Clove oil, the most used carrier in studies on chemosignals (Havlicek et al., 2010), was too persistent and too intense. Moreover Limonene might improve the positive mood (Heuberger et al., 2001), but the mood assessments (before and after Limonene presentation) allowed us to control for the mood changes due to Limonene.

7.4 Procedure

7.4.1 Discrimination screening

To ensure that the AND was not detectable within the limonene carrier solution, we tested the participants' ability to discriminate these stimuli using a three-way forced-choice ("triangle") test, as described by Amoore (1979) and

used in our lab (e.g., Li et al., 2008). We presented three opaque jars: one with the AND/limonene solution and two with limonene alone. The task was to find which one of three bottles had a different odor, after sniffing them seven times each. Six screening trials were performed in order to exclude participants who could detect AND, and to be sure that the two liquids were perceived as the same odor. We discarded all the participants with a good performance in this task ($> 4/6$ correct identifications). We excluded 1 female participant. Participants with a lower performance were recruited for the main study.

7.4.2 Main study

We used a within-subjects experimental design (Figure 7.1) with AND stimulation (AND in limonene vs. limonene only) as the independent variable and the amount of donated money as the dependent variable. In order to minimize any possible carryover effect due to the presentation of the odors, the two odor conditions (control vs. experimental) were run on different days (usually within 48 hours and always during the fertile menstrual phase), counterbalancing their order. The exclusion criteria (e.g., nasal congestion, menstrual phase) were double-checked before the second session started. The room was approximately 23.4 cubic meters in volume and was well-ventilated and there weren't any lingering odor present. Note that the interval between the odor presentation and the end of the decision-making task was from the 5th to 20th minute from the odor evaluation in both conditions. This time length is based on the observation that the effects of AND on physiology and behavior appear to be time-dependent, diminishing after the first 20-30 minutes after exposure (e.g., Saxton et al., 2008; Grosser et al., 2000). The total duration of the session was approximately 30 minutes.

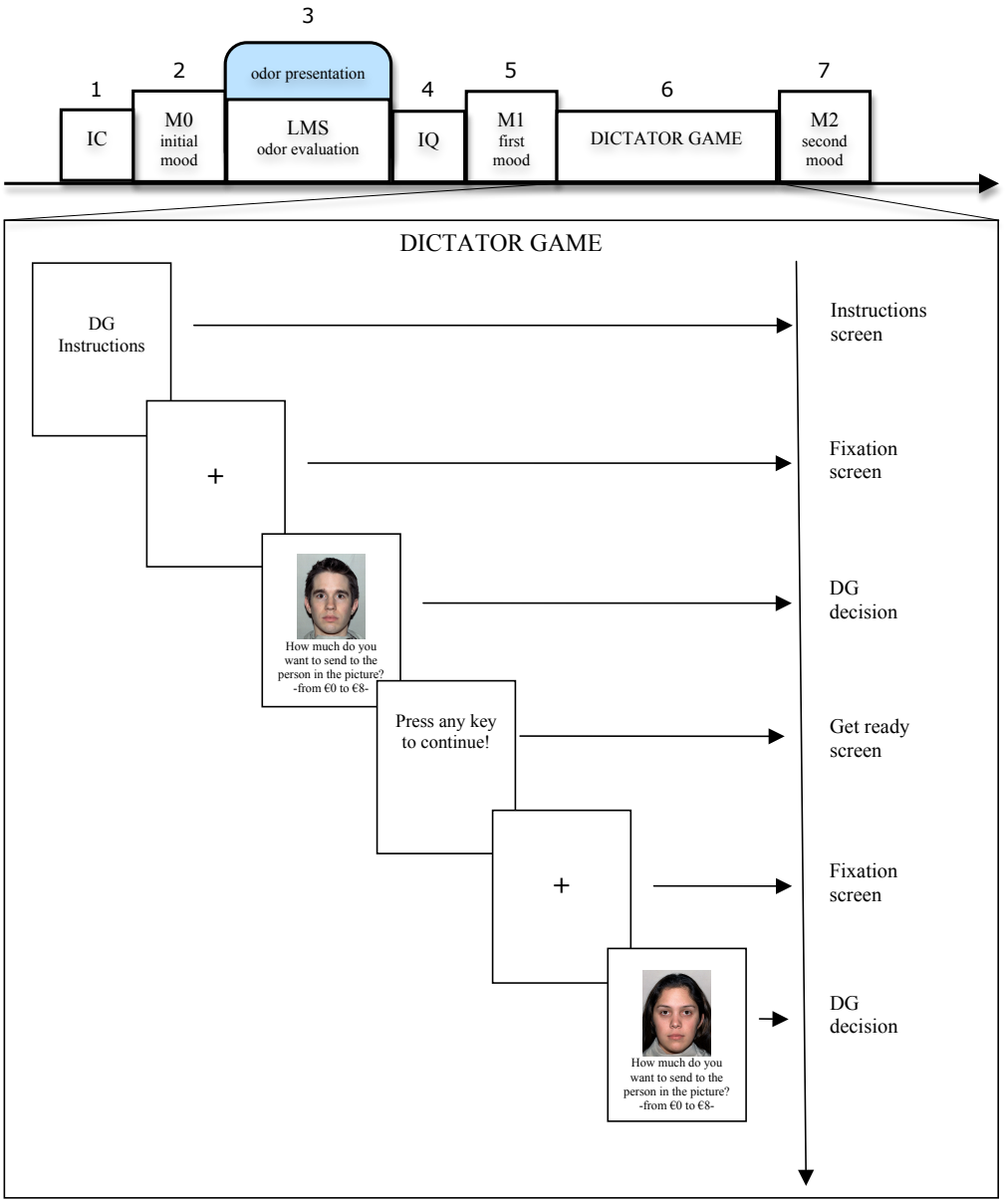

Figure 7.1: Schematic depicting experimental paradigm (upper panel) and typical trial sequence during the Dictator Game (lower panel). Each participant was tested with both odors (androstadienone in Limonene, Limonene alone). Key: IC, informed consent; LMS, Labeled Magnitude Scale; IQ, information questionnaires; DG, Dictator Game.

Phases of task:

1. *Informed Consent:*

   First, participants read and signed the informed consent form which outlined the experimental procedure.

2. *Baseline mood assessment:*

   Participants then filled out a paper-and-pencil questionnaire to rate their current mood ("baseline mood") in a non-scented room. They reported how strongly they were experiencing each of 16 different affective states (afraid, amused, angry, annoyed, anxious, bored, calm, confident, content, contemptuous, disgusted, embarrassed, happy, interested, sad, and stressed) on a 9-point scale from 1 = "not at all" to 9 = "very strongly" (adapted from Ekman et al., 1980). The "sexual arousal" item was added to the original version.

3. *Odor Evaluation:*

   We used the Labeled Magnitude Scale (Green et al., 1996) to assess odor intensity, plus the items pleasantness, familiarity, unpleasantness, and sensuality, added to the original version. Participants rated limonene or AND-limonene on a paper-and-pencil questionnaire, sniffing the bottle 7 times for each descriptor. This task lasted up to 5 minutes. We decided to present the compounds in this way (and not for example via an Olfactometer or epidermal application) to preserve the ecological validity of this study and to be sure that all the participants were not aware of the experimental aims and hypothesis of our study.

4. *Informational Questionnaire:*

   The participants completed the informational questionnaire, reporting

information about their health and drug usage and, if female, about their menstrual cycle.

5. *First mood assessment:*
   In the following steps of the experiment we used ePrime 1.0 (Psychology Software Tools, Inc) software (Schneider, Eschman, & Zuccolotto, 2002a,b). Participants again rated their mood ("first mood") after the initial evaluation of the odors, using the same scale utilized for the baseline mood assessment.

6. *Dictator Game:*
   We then presented the DG, in which the participants were instructed to divide €8 with a person presented opposite them on a computer screen. These pictures were taken from the NimStim set of facial expressions (Caucasian and Hispanic adult faces with neutral expressions were chosen; Tottenham et al., 2009). Participants played 24 trials of the DG. The pictures were in randomized order and every single pictures lasted on the computer screen until the participant's decision.

7. *Second mood assessment:*
   Finally, the last mood rating ("second mood") was presented, using the same method as above.

7.5 Results

7.5.1 Mood

To streamline analysis of the different mood ratings, we collapsed the Ekman rating scales into three clusters, "positive mood", "high arousal negative mood", and "low arousal negative mood", following prior work (Bensafi et

al., 2004). Below we will present the separate analyses of each mood cluster, plus the analysis on the "sexual arousal" scale. A repeated-measures 3x2x2 ANOVA on positive mood (dependent variable) was carried out with 3 independent variables: time (3 levels within-subject, corresponding to baseline, first, and second mood assessments), odor (2 levels within-subject, AND with Limonene, and Limonene alone), and the participants' gender (2 levels, between-subject). The analysis shows a significant effect of time ($F(2, 34) = 10.65$; $p < .001$) and a significant three-way odor-by-gender-by-time interaction ($F(2, 34) = 4.25$; $p = .022$) on positive mood (Figure 7.2). The other main effects and interactions were not significant. Follow-up contrast analyses of the interaction effect, focusing on the first two time-points (i.e., baseline mood vs. first mood), revealed a significant effect ($F(1, 35) = 5.1$; $p = .03$), such that there was a larger mood increase for female (vs. male) participants for the AND (vs. limonene) condition.

We also repeated the 3x2x2 ANOVA (time, gender and odor) for the other mood clusters. For "low arousal negative mood" there was a significant effect of time, $F(2, 34) = 4.25$; $p = .023$, and of the time-by-odor interaction, $F(2, 34) = 4.27$; $p = .022$). For "high arousal negative mood" there was a significant effect of time, $F(2, 34) = 8.7$; $p = .001$, and of the time-by-gender interaction, $F(2, 34) = 5.44$; $p = .009$). No significant effects were seen regarding ratings of "sexual arousal".

7.5.2 Mood and Dictator donations

We first examined the effect of AND on donations. Donations were increased in the presence of AND (Mean = €3.65; SD=1.41) compared to the limonene control condition (Mean = €3.42; SD = 1.53), with a difference that was significant ($T(36) = 1.9$, $p < .05$, paired t-test, one tail). To gain

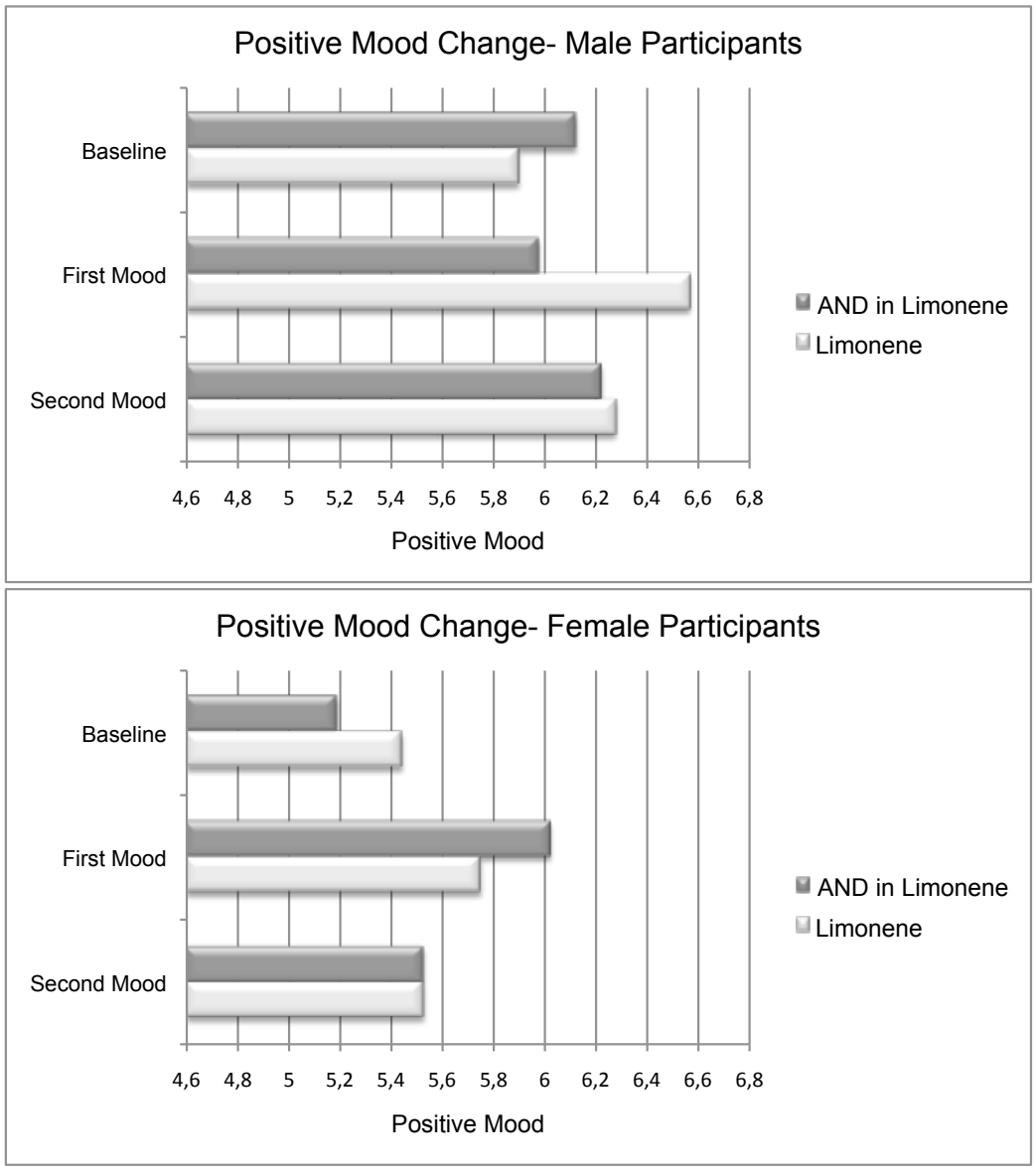

Figure 7.2: Change in positive mood level across the three mood ratings, differentiated by odor stimulus type and gender. AND, androstadienone.

a more systematic understanding of the factors that influenced the donation amount, we used the Generalized Estimating Equations model (GEE; Hosmer & Lemeshow, 2000) that allows inclusion of categorical within-subject factors. The following factors were entered into the model: AND stimulation (a categorical, within-subjects variable), gender (a categorical, between-subject variable), Δpositive mood and Δlow-arousal negative mood (from baseline to first, two continuous variables), and the amount of the donation (a continuous variable). Mood was expressed in terms of difference between the baseline mood value and the first mood, in order to measure the mood change generated by the odor stimulation. The mood clusters unaffected by the chemosignal manipulation were not included in the analysis. We tested different GEE models, and compared them using a Goodness-of-Fit statistic, the Quasi-Likelihood Under Independence Model Criterion (QIC).

The model with the best Goodness-of-Fit statistic (QIC=148.7) and with significant factors showed two statistically significant interactions: "AND stimulation by Δpositive mood" (Wald$\chi^2(1) = 6.11$, p = .013) and "gender by Δpositive mood" (Wald$\chi^2(1) = 11.92$, p = .001). These findings indicate that AND stimulation and gender both affect the donation amount, but critically, the strength of effects depends on the variation of the positive mood. These results are broadly coherent with the literature on putative chemosignals and mood alterations, which points toward a selective effect of AND on positive mood, only for the female participants (Bensafi et al., 2004).

Because the different reactions of female and male participants are a crucial element of this study (as indicated by the significant interactions in the "Mood" and "Mood and Donations" analyses) we ran two separate GEE models to study in detail the effect of AND on female and male partic-

ipants. The factors used in these models were the putative chemosignal stimulation,Δpositive mood, and the donation amount. In the GEE model for the male participants (QIC = 95.70) only the Δpositive mood was significant (Wald$\chi^2(1) = 3.99$, β = -.49, p = .046). On the contrary, the model for the female participants (QIC = 59.42) showed a significant interaction for AND stimulation by Δpositive mood (Wald$\chi^2(1) = 3.85$, β = .61, p = .050). Figure 9.3 illustrates this interaction: in the AND condition, the change of the positive mood significantly predicts the donation amount, β = .58, t(17) = 2.9, p = .01, and it also explains a significant proportion of variance in the donations, R^2 = .33, F(1, 17) = 8.4, p = .01. On the contrary, in the limonene condition the Δpositive mood was not a significant predictor (F(1, 17) = .03, p = .86). Note, for example, that for the same Δpositive mood (e.g. +1.8), the participants within the AND condition donated more (mean = €4.19) compared to the limonene condition (mean = €2.96).

7.6 Discussion

Our experimental results indicate that androstadienone can increase the propensity to behave pro-socially, such as, for example, being a more generous "dictator". The initial analysis on mood demonstrated that AND stimulation reduced the low-arousal negative mood and improved the participants' positive mood, but the latter effect was limited to the female participants (as in Bensafi et al., 2004). In parallel, data analysis of the DG (with male and female participants) revealed that, in the presence of AND, greater enhancement of positive mood corresponded to higher donations, a result in accordance with the literature on mood and altruism (see Carlson et al., 1988). However, because the effect of AND on the positive mood was dif-

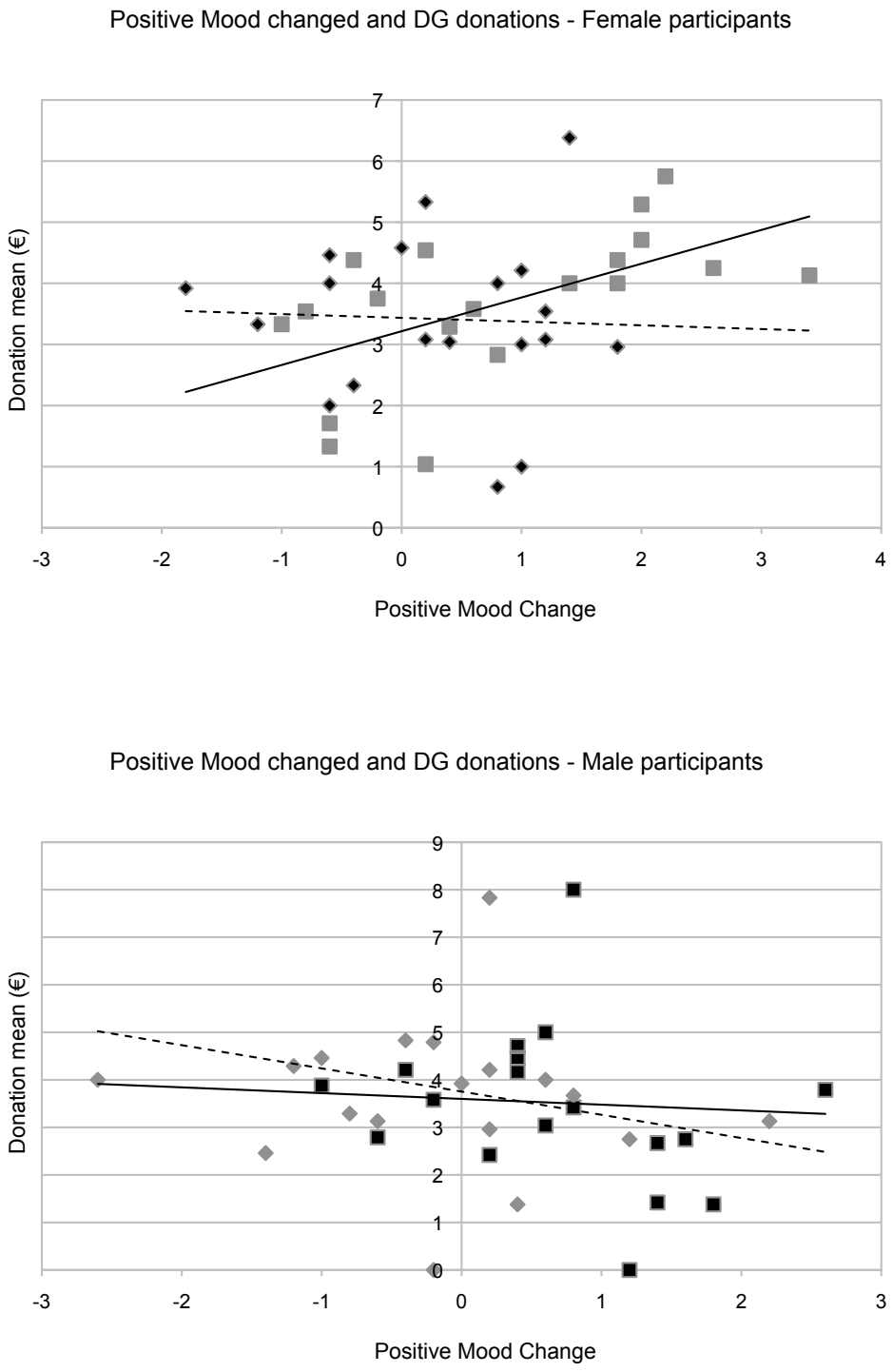

Figure 7.3: Interaction between putative chemosignal manipulation and Δpositive mood (Positive Mood Change) on Dictator Game donations in females and in males (the continuous regression line refers to the Limonene + AND condition condition, the dashed regression line refers to the Limonene condition). Diamonds, Limonene + AND condition; squares, Limonene condition.

ferentiated by gender, we conducted a follow-up analysis to show that this effect was particularly strong for female participants: in the limonene condition there was no relationship between mood and donations, whereas in the AND condition women with a comparable positive mood change made greater donations.

Our findings are in broad agreement with the previous literature indicating an effect of AND on mood ratings in a gender-specific way. However, the results presented here mark a novel extension of these findings by highlighting a specific and independent effect of AND on pro-social behavior. From a neurobiological perspective the fact that AND had partially separable influences on positive mood per se and on donation amounts implies that this odor compound may mediate its effects on altruistic behavior through dual and dissociable neural pathways. Future work that combines these paradigms with functional neuroimaging techniques will be important to test these predictions.

In conclusion, this study opens up a new multidisciplinary approach that combines putative olfactory chemosignals with economical models of decision-making to address questions about implicit olfactory control of higher-order cognitive operations. Our work also has potential implications for development of new studies aiming to induce mood states in the absence of overt awareness. Based on the findings presented here, it seems likely that not only smiles and gifts (Isen, 2008; Mellers et al., 2010), but also odorous signals, can induce changes in affective states that interact with our choice "to be, or not to be" a generous person.

7.7 Acknowledgments

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Part III

Conclusion

CHAPTER 8

General discussion

The general discussion is structured into three main parts. First, an attempt to explain the findings focusing on the general aim will be made. Second, each specific aim of the thesis presented above will be examined and discussed. Finally, conclusions will be reported.

8.1 General aim focus

The experimental work included in the present thesis aimed at extending to the decision making domain the knowledge about the effect of olfactory stimuli on psychological variables. The results provided empirical evidence that there is an association between odors and decision making processes involved in the decision to donate to public goods, as well as between chemosignals and decision to donate to persons.

The findings reported here also prove that there is an effect of odors not only in the decision domain, but in the association between odors and concepts. Actually, we found a facilitation effect on the lexical decision task when a pleasant odor is presented (compared to the no odor condition). In the decision domain the associations between odor and concept seem to be helped by the congruity between an odor stimulus and the object of the donation. However, in the lexical decision task the congruity relation (and the resulting facilitation effect) between odor and word was not highlighted. Thus, it seems that in the lexical decision task the crucial attribute, capable of reducing the RT, is the presence of a pleasant odor. Actually, the odor presence during a lexical decision task results in a increase of performance efficiency (i.e., faster response times). Interestingly, all the pleasant odors and not only the odor semantically related with the words showed a facilitation effect.

With regard to chemosignals, our findings confirmed previous results about the mood induction due to the presence of AND as well as the crucial role of the compound dosage in the emotional states modulation. Furthermore, we found an effect (main effect or mediated by the mood) of the chemosignal presence on the decision to donate to persons in a Dictator or Trust Game. Our findings show an increase of donation in presence of low and high concentration of AND, compared to the control condition in which only the mask odor was presented. Moreover, these effects are modulated by the participants' gender and by the AND dosage. Women, as reported in many studies mentioned above on the effect of AND in different psychophysiological parameters, are easily influenced by the presence of AND.

8.2 Critical summary of empirical findings

An overview of this study, its implications and some final considerations are outlined in the following sections.

8.2.1 Do ambient odors have an influence on value attribution and the decision to donate?

The results presented in Paper I and in Paper II indicate that ambient odors guide our decisions. In particular, all the pleasant ambient odors have an effect on the decision to donate in favor of a public good. In addition to this evidence we found that a particular category of odors have a stronger impact on these decisions. The congruity odor-decision consisted in an odor that is semantically linked with the decision domain (e.g., lemon odor and the decision to financially support the maintenance of a lemon garden). The congruity between the odor and the decision task affects the decision process, making the persons more generous (compared to the other pleasant olfactory condition and to the control condition). Moreover, this effect is showed in both the decision making settings that we used: in the hypothetical and in the real decision. In Paper I-Experiment 1, participants were presented with a scenario that requested them to decide if they wanted to donate an hypothetical amount of money to prevent an environmental hazard, and in the Experiment 2 we presented the same decision task but we asked the participants to give a real monetary contribution (taken from their show-up fee). In both cases the more generous amount of money was donated in the congruency condition.

8.2.2 What are the previously found effects due to?

We demonstrated that some psychological mechanisms associated with ambient odors influence the decision to donate. We could ascribe this effect to a "semantical accessibility" principle. Actually, Paper I and Paper II reported a strong effect on the decision only if it was present a pleasant odor, congruent with the decision task. It seems that only the right odors (pleasant and congruent) could enhance the availability of a concept and then act on the decision to donate. In addiction, Paper II showed that the effect founded on the decision tasks is not extended to different tasks such as the lexical decision one. In the lexical decision tasks all the pleasant odors facilitate the performance, making the participants faster in the word recognition.

8.2.3 Does the sensorial modality have an effect on the congruity effects that we found?

The sensorial modality has a crucial role in the congruity effects. In particular Paper II reported our findings in two different sensorial modality: olfaction and vision. In particular, we found that the olfactory modality plays a stronger effects on different types of tasks, word recognition and decision, and then in different cognitive processes. We presented two congruent and pleasant stimuli: a lemon picture and the lemon odor. The results show that the olfactory stimuli have a stronger effect on both tasks. When participants inhaled a congruent odor were more fast in the word recognition and more generous in the decision task (compared to the congruent visual stimulus condition). A possible explanation of these results may refer to different information processing modes: one for the olfactory stimuli and one for the visual ones. The odors seem to reach more quickly the limbic system and

then driving the participants' responses using a process more emotional then analytical.

8.2.4 We found some interesting effects of odors on decision making. Is it possible to extend the effect of odors in different donation domains?

We examined this point trying to use not only odor related with things, but human endogenous odors, such as the chemosignal androstadienone (AND) to associate an odor with persons and then to donation toward persons. We measured the participants' altruism using a Dictator Game and trust using a Trust Game. The results showed that the chemosignal presence has an effect on the decision process, increasing the amount donated.

8.2.5 Are the findings due to the chemosignal dosage?

It is possible that the chemosignal dosage has an influence on the cognitive processes. In particular, we used two different dosages of androstadienone: 250μM in Paper III and 650μM in Paper IV. The rationale behind these choices is that Bensafi et al. (2004)[1] study showed a difference in the participants mood when they inhaled high and low dosages. In particular, Bensafi and colleagues reported changes in mood only when androstadienone at high dosage was presented. Women exposed to the 650μM concentration showed an higher level of positive mood, while men presented a lower level (compared to the low dosage exposure at 250μM). Our findings show the same

[1]Bensafi, M., Tsutsui, T., Khan, R., Levenson, R. W., & Sobel, N. (2004). Sniffing a human sex-steroid derived compound affects mood and autonomic arousal in a dose-dependent manner. *Psychoneuroendocrinology, 29,* 1290–1299.

mood patterns, confirming that the compound dosage has a crucial role in this field of studies.

8.2.6 Are the findings driven by a mood effect?

Our findings seem to be driven by a mood effect, but in different ways. In Paper III our results showed an increase in the positive mood level when participants were exposed to androstadienone. In addiction, Paper IV showed the same results for the positive mood of the female participants only. Interestingly, the dependent variable (i.e., the donation amount) had the same trend in both studies. However, because the effect of AND on the positive mood was differentiated by gender, in Paper IV our result show that in the AND condition women with a comparable positive mood change made greater donations (compared to men).

8.2.7 Is the dosage responsible for changing in the decision to donate in a Dictator Game?

The chemosignal dosage is very important. Previous studies (Bensafi et al., 2004) showed that at low chemosignal concentration (250μM) and at high concentration (650μM) we could find opposite results. The concentration that we used were the same used by these authors. In particular, we found a main effect of AND on the decision to donate only in case of exposure to the lower AND dosage. When the dosage was higher the effect on the donation was mediated by the positive mood increase due to the AND presence.

8.3 Concluding remarks

To conclude, the present thesis demonstrated that the decision processes can be modulated differently depending on the presence of a specific pleasant odor or a chemosignal. The results emerging from the present work suggest that when people are exposed to an odor, usually tend to do more altruistic choices. This effect is stronger when the odor is semantically congruent with the decision task. These findings show the importance of the impact of olfactory stimuli in our life. Furthermore, these findings could be beneficial in public good or support campaigns, inducing people to behave more altruistically when they experience an odor appropriate to the decision task. Finally, our findings could be a novel demonstration of the action of human chemosignals on high level cognitive processes. In particular, in the light of what has been presented above, androstadienone seems to act in synergy with psychological and physiological processes, leading changes in decision making.

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